TOO GOOD TO WASTE

UNLOCKING THE POTENTIAL OF CONSTRUCTION AND DEMOLITION WASTE

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Abstract

The negative impact of waste materials on the environment is increasing globally. In Tāmaki Makaurau Auckland, it is causing destruction to wetlands, landscapes, and marine habitats. Auckland Council has responded to the problem by setting a bold goal, a vision of zero waste to landfill by 2040. This research by design project seeks to support that vision.

Too Good to Waste focuses on the problem of waste from construction and demolition, specifically timber waste. The architectural proposition proposes repurposing an underutilised car parking building in Mangere City to accommodate two functions, firstly, to establish a headquarters for the Brown Butterbean Motivational (BBM) Programme which runs free fitness programmes focusing on helping people to achieve healthy weight goals. It is targeted at Pacific Islanders and Maori across Auckland. The second function specifically addresses the research question by establishing a construction and demolition waste hub for sorting and processing timber waste products and to generate functional and useable materials. Space is also provided for free carpentry and woodwork craftsmanship courses.

Auckland Council's 5R waste management hierarchy, and further research by Hebel et al in *Building from Waste,* are used to establish a design methodology for *Too Good to Waste*. Four key architectural precedents, which demonstrate either one or more waste management principles or inform the programme, also inform the design.

The resulting design addresses a social need while demonstrating the potential of what are currently regarded as waste materials from the construction industry. By repurposing an underutilised building, rather than demolishing it, the creation of yet more waste is avoided. Throughout the project, the use of waste materials from either the repurposing process, the processing hub, or the workshops, is celebrated, demonstrating their value and potential. These materials are simply too good to waste.

Contents

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May the Lord bless you all abundantly.

Introduction

Background

The negative impact of waste materials on the environment is still advancing globally, and this includes changes in the climate. It is clear that increases in human activities contribute to global warming. Nasa has highlighted that there has been an increase in global temperatures since climate observations of the Earth started in the 1800s; this is due in part to natural activity like volcanic eruptions, but mainly to unnatural human activity such as the burning of fossil fuels.[1] What is more, the construction industry contributes heavily to this problem through CO_2 gas emissions during the manufacture of building materials, with construction activities (machinery), and by creating construction and demolition (C&D) waste on site, which then leads to the release of methane gas into landfills through decomposition.

In Auckland, these same activities continue to cause destruction to wetlands, landscapes and marine life. As a result of this awareness, Auckland Council has set a bold goal of a zero waste to landfill vision by 2040.[2] Auckland Council has highlighted that the main reasons for this deterioration are the city's growth, the effects of climate change, and poor decision-making.[3]

The level of exponential population growth pressures the construction industry to erect and establish new infrastructure, buildings and residential developments. An increase in waste production then becomes inevitable; recently, 1.6 million tonnes of waste has been sent to landfills, which cost taxpayers $5-8 million to operate annually.[4] It is undeniable that this sequence of events will continue to affect natural ecosystems, jeopardising soil and water quality, as well as exacerbating the effects of climate change – and ultimately endangering humanity.[5]

Cognisant of this emerging and complex problem, in 2012 Auckland Council introduced its goal of zero waste to landfill by 2040. This aligns with the Waste Management and Minimisation Plan 2018,

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[1] "Overview: Weather, Global Warming, and Climate Change", Global Climate Change, Nasa, last updated May 16,2022, Global Warming vs. Climate Change | Resources – Climate Change: Vital Signs of the Planet (nasa.gov)

[2] *Auckland Council, Auckland Waste Management and Minimisation Plan 2018, 17, Waste Management and Minimisation Plan (aucklandcouncil.govt.nz)*

[3] "Auckland's key challenges", Auckland Council, accessed April 12, 2022, Auckland's key challenges (aucklandcouncil.govt.nz)

[4] "How much rubbish goes into the Auckland landfill annually?", 0800Dumpme, updated December 13, 2019, How much rubbish goes into the Auckland landfill annually? | 0800 DUMPME

[5] Tom Crick, "New report signals nine top environmental issues facing New Zealand", Stats, updated April 18, 2019, New report signals nine top environmental issues facing New Zealand | Stats NZ

which aims to reduce all waste streams to landfills by 30% by 2027.[6] For this, Auckland Council was recognised globally as the most innovative council for climate change strategies in 2017.[7] However, waste continues to pour in by the tonne annually[8], compelling Auckland Council to procure additional waste management sites.[9] Furthermore, the council has highlighted that out of all waste streams,

> "Waste from construction and demolition holds the greatest potential for waste minimisation partly because it is the biggest source of materials going to landfill."[10]

Clearly, C&D waste has a huge impact on the environment and on climate changes.[11] Therefore, much needs to be done to raise awareness around the impact of this waste. In the words of the chair of the Environment and Climate Change Committee, Councillor Richard Hills,

> "We need to enable people to make change by showing them how to do it and creating a culture around reducing waste…"[12]

A comment from *Building from Waste*, by Dirk E. Hebel, Marta H. Wisniewska and Felix Heisel, provides a focus that will help revolutionise the future of the construction industry.

> "Since the material resources used in the building sector have been accumulated in our cities for centuries, they are more and more exhausted at their places of origin. The mines of the future are therefore not underground, they are to be found in our built environment."[13]

Hebel et al's perspective on waste materials encourages a circular economy, which will primarily bring positive impacts to the environment, as well as to the economy.

Project Outline

The project is about designing a building with dual purpose and function; that is, the headquarters for Brown Butterbean Motivational (BBM) Programme, and a C&D waste hub, both to be

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[6] "Our mission – our goal", Make the most of waste, accessed April 12, 2022, About | Make The Most of Waste

[7] "Auckland Council's zero-waste leading the world", Auckland Council, Our Auckland, updated October 31, 2017, Auckland Council's zero-waste leading the world - OurAuckland

[8] *Auckland Council, Auckland Waste Management and Minimisation Plan 2018, 6.*

[9] Nikki Macdonald, "'We are extremely wasteful': Is it time to dump the dumps?", Stuff, updated August 1, 2021, 'We are extremely wasteful': Is it time to dump the dumps? | Stuff.co.nz

[10] "Why construction waste matters", Make the most of waste, accessed April 12, 2022, Why construction waste matters | Make The Most of Waste

[11] "Building the path to zero waste", Auckland Council, Our Auckland, updated October 23, 2020, Building the path to zero waste - OurAuckland (aucklandcouncil.govt.nz)

[12] Our Auckland, "Building the path to zero waste".

[13] Dirk E. Hebel, Marta H. W Wisniewska, Felix Heisel, *Building from Waste: recovered materials in architecture and construction* (Basel: Birkhäuser Verlag GmbH, 2014), 27.

accommodated in one building. BBM runs free fitness programmes focusing on helping people to achieve healthy weight goals. These are targeted at Pacific Islanders and Maori across Auckland.

Meanwhile, the main purpose of the C&D hub is to sort and process wooden waste to generate functional and useable materials, and also to offer free carpentry and woodwork craftsmanship courses.

Aims and Objectives

The overall aim of this research is to help achieve Auckland Council's zero waste goal by 2040, and the goal is to demonstrate a project that supports this by integrating C&D waste into the project design. This project will also encourage Aucklanders to make changes for the better by taking good care of their surroundings in order to maintain and benefit from a healthy environment for the sake of future generations. Specifically, a key goal is to reduce construction and demolition waste streams that end up in landfills. To achieve this, the project aims to challenge the mentality of seeing waste materials as worthless, but instead to uncover and showcase their potential, demonstrating that waste materials can be equally as valuable as new materials.

In line with this, the proposed building itself will be a tangible exhibition of these solutions to educate individuals and communities, and to encourage them to develop strategies around C&D waste reduction. It will illuminate ways to facilitate and support the practical application of waste reduction strategies as part of new building development. Lastly, the project will also aim to provide jobs opportunities for people and to develop their creative skill sets.

The first objective taken to execute the aim of the project is the incorporation of a strong social, ethical enterprise that is proposed to help the community through physical activities and dietary guidance. The second is to include a hub as an educational centre and meeting destination where the public and tradespeople can source materials and exchange ideas and techniques on dealing with C&D wooden waste.

Research Question

The aims and objectives outlined above lead to the research question: How can architecture demonstrate the use of waste from construction and demolition sites to help achieve Auckland Council's vision of zero waste by 2040?

Scope and Limitations

Firstly, this research is driven by one of Auckland's major issues, which is environmental degradation. With that in mind, this assignment focuses its investigation entirely on one of its causes, namely, waste materials, while prioritising working with C&D waste. Moreover, the study

will examine Auckland Council's current waste reduction strategies as well as its future plans. Lastly, the study explores architectural solutions best suited to mitigate this dilemma.

With the intent to build, the architectural proposition involves removing parts of an existing car park building structure, which would require analysis and advice from a structural engineer. For the purposes of this research, it has been assumed that the proposed changes will not compromise the integrity of the structure. Therefore, this project will require manual labour to sort and produce useable waste materials necessary for the overall building. Most significantly, the materials will be sourced within a 20-kilometre radius of the project site. This choice offers multiple benefits for the project completion. For example, materials will be sourced close to the project site, implying that relatively low transport costs will be incurred in delivering these. In addition, material shortages during the project implementation will be quickly addressed by accessing suppliers located within the 20-kilometre radius of the project site. As a result, there is a reasonable expectation that the project implementation will be executed as planned to deliver the desired outcomes. Energy, time and cost are three major contributing factors that could delay the build. In keeping with this, another limitation of the project is the scarcity of cutting-edge technology in New Zealand such as, but not limited to, sorting machinery and equipment. If essential technologies are at hand, then time, cost and energy constraints can be greatly reduced.

Finally, one potential barrier to this research is the consenting process for the final C&D waste materials to be used on the project. All projects must comply with New Zealand Building Code. Correspondingly, meeting engineers' specifications is a requisite which could theoretically delay the consent stages of the project. Another limitation of the project is the exclusion of other waste materials that have the potential to be used as building materials. This is chiefly because this assignment is based entirely on C&D waste and its effects on the environment.

State of Knowledge in the Field

Numerous research studies have been conducted in the past regarding waste reduction strategies, both in written and built form. Therefore, this study will examine Auckland Council's approach using the 5R waste management hierarchy (reduction, reuse, recycle, recover and residual disposal)[14] and will also explore waste reduction tactics (densified, reconfigured, transformed, designed and cultivated) highlighted in *Building from Waste*, by Hebel et al, which will be elaborated on later in the content. Both will be supported by case studies and other literature that express clarity in the research.

[14] *Auckland Council, Auckland Waste Assessment 2017, 120.*

The first 'R' is Reduction, which is considered the most favoured option for waste minimisation. This process involves reducing the extraction of raw materials, which in turn reduces the amount of material going to landfills. The second 'R' is the concept of Re-use, which is about using materials salvaged from demolition or construction sites. The process of deconstruction is intertwined with this 'R' where most, if not all, components of a dismantled building have a chance to be re-used. The next 'R' refers to Recycling, which is the reprocessing of waste materials and transforming them into new building materials. Currently, this process is carried out at over 100 recycling plants across Auckland. The last two 'R's – Recover and Residual – rely on the above 'R's: whatever is not fit for recycling, reusing or can't be reduced is used to generate energy for the recycling process, and whatever cannot be recovered goes directly for residual disposal at landfills.[15]

Furthermore, the research will investigate architectural precedent buildings with significant aspects that provide inspiration in the waste reduction focus and also in the development proposal design project. In addition, the research will extend into a light investigation of the Living Building Challenge (LBC), as one of its design principles (material) is strongly aligned with the focus of the research.

The architectural precedent buildings chosen for this project are the Slaughterhouse in Shanghai, China, which symbolises the 'Re-purpose' process by re-using the building multiple times for different purposes. The Flagship Education Centre, considered the first Living Build Challenge in Auckland, is also helpful as it is built using locally sourced C&D waste materials. The Ningbo Museum building in Zhejiang, China, delivers architecturally significant characteristics by utilising recycled materials as structural elements. Lastly, the Athletic Centre in Nosara, Costa Rica, reflects a perfect design of connecting occupants and nature through spaces formed through manipulation of building elements and the site. Both the literature reviews and architectural precedent studies contribute to the development of the proposed design of the project.

Methods

In order to materialise this research into a building project, five different steps were taken, namely: data collection, model making, informal discussion, desktop research and an iterative design process.

[15] *Mehrnaz Rohani, Ting Huang, Leon Hoffman, Mark Roberts, and Barbara Ribeiro, Auckland Council, Knowledgeauckland, Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill. A case study based on HLC Ltd development in Auckland, Technical Report 2019/009, July 2019, 5, Cost benefit analysis of construction and demolition waste diversion from landfill. A case study based on HLC Ltd development in Auckland (knowledgeauckland.org.nz)*

To better understand the amount of C&D waste produced on sites, an investigation was carried out in person at three construction sites, two demolition yards, and two demolition sites within Auckland. The aim of these assessments was to broaden the understanding of what comprises C&D waste. It will also support informed decision-making and planning around which C&D waste materials can be integrated into the project design.

After concluding site measurements, C&D waste material craftmanship concepts were developed through modelling incorporating various assembly techniques. The craftsmanship concepts were also inspired by the work of New Zealand artist Gregor Kregar. His sculptures, located throughout New Zealand, and, in particular, one piece, which was modelled from recycled timber, have a significant artistic appearance that strongly influenced the design development of the proposed project.

Additionally, an informal discussion was conducted with David Letele regarding BBM's programme and its vision. Letele confirmed that BBM needed a new complex, a place where members of the public can feel safe and comfortable when they seek health improvement via physical programmes, and a place where they can gain knowledge to improve their diet.

Furthermore, constant desktop research was crucial in gathering the most up-to-date data and credible resources to guide this project. This also contributes to the iterative design process where the project can conceptualise and develop to formalise the final design decisions. This was developed by integrating materials discovered during the site assessment, and also through exploration of design techniques.

Results of the Research

The research findings point to the fact that there is more than one way to address C&D waste and that these avenues need to be explored. With that said, there remains a gap in the general public's awareness about this issue – without communities' and societies' buy-in, innovative solutions to C&D waste are rendered futile. I firmly believe that one of the ways to start addressing this issue now is erecting accessible C&D waste hubs across Aotearoa New Zealand. Depending on how this is run, within communities, it can promote greater collaboration between local and government bodies. Another possible solution is encouraging the design and construction of buildings using C&D waste.

In the 15 years of my career in the building industry, seeing C&D waste has become the norm. Yet, as I reflect on it now, I had minimal to no awareness as to how detrimental it can be to the environment. Through this research project, my perspective on C&D waste and all types of waste,

for that matter, has completely shifted. The research findings have convinced me to be part of the solution, albeit as only a small cog in the bigger system. As an aspiring architect, I will endeavour to utilise C&D waste materials as first choice rather than newly manufactured products, which often exacerbate diversion to landfills. I acknowledge that this will necessitate time spent on strategic material investigation and sourcing, but nevertheless, it is a process that I am now willing to invest in.

Waste Management

It is necessary to understand that zero waste does not mean that zero waste is produced; instead, it is more about how to reduce waste production.[16] Kamikatsu, a town situated on the island of Shikoku in Japan, was declared to be the first town in Japan to formally issue a zero-waste declaration in 2003, whereby all waste produced by its residents is recycled, leaving nothing for landfills.[17] This is achieved through a recycling centre where all waste processing activities take place; it is also used as an education centre for the exchange of ideas and strategies regarding waste management, and a place where residents or visitors can leave unwanted goods for others who have an interest in them, to use for free .[18]

Waste Management is defined as any action taken or required to manage waste materials that come in gas, liquid and solid form which are required to be processed and monitored. It can be classified into 5R hierarchies: reduction, re-use, recycle, recover and residual disposal.

> Ko te orange o Ranginui rāua ko Papatūānuku tonu
> kei roto I ngā ringaringa o tēnā me tēnā
> *The survival of the Father Sky and Mother Earth*
> *Rests in the hands of each and every one of us*

Now more than ever there is an emphasis on waste and how societies are the major contributing factor to its exponential growth. Correspondingly, Auckland Waste Management and Minimisation Plan 2018 (Te Mahere Whakahaere me te Whakaiti Tukunga Para i Tāmaki Makaurau) was encouraged by the Ministry for the Environment to utilise the 5R (reduction, reuse, recycle, recover and residual disposal) waste management hierarchy framework and help encourage C&D waste

[16] Andrew Krosofsky, "Will a Zero-Waste Society Ever Be Possible?" Green Matters, updated April 12, 2021, Is a Zero-Waste Society Possible? (greenmatters.com)

[17] Alyn Griffiths, "Kamikatsu Zero Waste Center by Hiroshi Nakamura is built using waste materials", Dezeen, updated November 9, 2021, Kamikatsu Zero Waste Center is built using waste materials (dezeen.com)

[18] "Zero-Waste Communities Across the Globe", *zerowaste* (blog), March 3, 2021, Zero Waste Communities around the World | zerowaste.com

diversion from landfills.[19] Through this same waste management hierarchy, Auckland Council established the 5Rs specifically to

> "…sets out priorities for using resources in the most efficient way and reducing the amount of waste that is produced."[20]

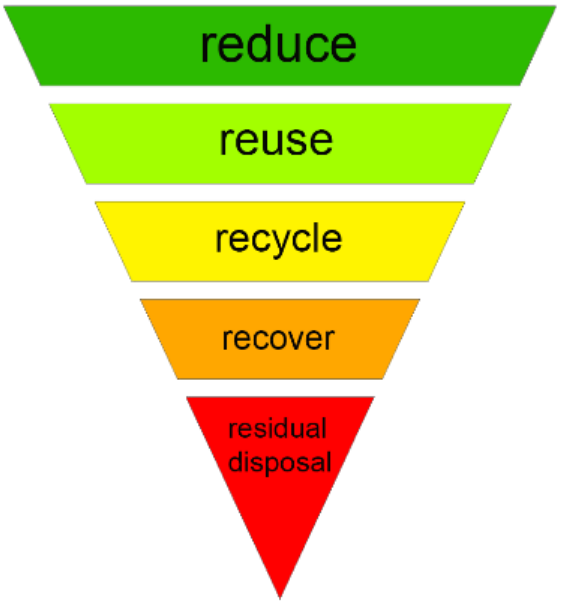

Figure 1: Waste Management Hierarchy

Reduction

The first technique is simply the concept of reducing waste. Reduction of waste is at the top of the hierarchy for waste management. It is considered the most effective approach to diminishing waste[21] and at this stage, the best time to effect social, economic and environmental change negatively or positively is where the design of materials is finalised.[22] This same perspective is backed up by Rohani et al in a report affirming that "reduction is always the best option to minimise waste".[23] This concept of reduction has two main elements, namely, 'avoiding' and 'lessening'.

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[19] *Rohani et al, Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill. A case study based on HLC Ltd development in Auckland, 4.*

[20] "Building Out Waste: A guide for developers and building contractors", Auckland Council, Make the Most of Waste, accessed April 12, 2022, building-out-waste.pdf (makethemostofwaste.co.nz)

[21] "Urban Sanitation and Solid Waste Management", Open WASH, Ethiopian WASH, accessed April 12, 2022, https://www.open.edu/openlearncreate/pluginfile.php/172418/mod_resource/content/1/Urban_Sanitation_and_Solid_Waste_Management.pdf

[22] Ethiopian WASH, "Urban Sanitation and Solid Waste Management".

[23] *Rohani et al, Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill A case study based on HLC Ltd development in Auckland, 5.*

Avoiding

This concept can be likened to a situation whereby one wants to go to a dairy down the road on a nice day for a bottle of milk but cycles instead of driving. He/she chooses to avoid a means of transportation that saves time but has negative environmental effects and, instead, utilises an alternative, eco-friendly option. LEARNZ Organization defines a reduced waste management approach as:

> "…avoid the unnecessary use of resources such as materials, energy and water. It means there is less waste to manage."[24]

To avoid is more than just 'avoiding' – it requires extra attention to changing daily habits[25] to be more aligned with sustainable living. From a New Zealand perspective, this methodology was employed in 2019 when the government banned the production and use of single-use of plastic bags of 69 microns or less in thickness and derived from bio-based elements.[26] The change was quickly adopted and accepted by New Zealanders, demonstrating that this particular regulation is another step forward in preserving and protecting the environment.[27]

Lessening Concept

The Environment Protection Agency (EPA) specifies that the most successful way of reducing waste is to generate less in the first place. The organisation has lobbied for a change in current practice within households and business sectors. One illustration of this concept of 'lessening' is through printing activities in offices. Employees are encouraged to print using double-sided pages instead of single-sided. This simple but effective change in office practice can greatly contribute to the reduction of paper used and, in effect, mean less wastage.[28]

This perspective is supported and encouraged by William McDonough and Michael Braungart in their book, *Cradle to Cradle,* highlighting

[24] "The 5 R's of Waste Management", Core, LEARNZ, accessed April 12, 2021, The 5 R's of Waste Management | LEARNZ

[25] "Managing and Reducing Wastes: A Guide for Commercial Buildings", United States Government, Environmental Protection Agency, updated April 4, 2022, Managing and Reducing Wastes: A Guide for Commercial Buildings | US EPA

[26] "Single-use plastic shopping bag ban: Facts for businesses", New Zealand Government, Ministry for the Environment, updated June 21, 2021, Single-use plastic shopping bag ban: Facts for businesses | Ministry for the Environment

[27] Ministry for the Environment, "Single-use plastic shopping bag ban: Facts for businesses".

[28] Environmental Protection Agency, "Managing and Reducing Wastes: A Guide for Commercial Buildings".

> "Do whatever you can, no matter how inconvenient, to limit your consumption. Buy less, spend less, drive less. Have fewer children – or none."[29]

Re-use

The concept of 're-use' involves using the same product over and over again without transforming or altering its original form.[30] Clinton County Organisation, Ohio, USA, referred to it as a second-best option in waste management. Both ancient and modern societies have long been practising this waste management method and it remains widely used today. An example of this is when people donate second-hand belongings to community centres or to others instead of disposing of them, when they would most likely end up in a landfill.[31] Auckland Council refers to the re-use of materials that can be related to C&D waste such as joinery, fixtures or timber obtained from deconstruction processes.[32] This is clearly showcased through Le Corbusier's chapel at Ronchamp, where he re-uses rubble from the old chapel to fill the structural walls of the new chapel.

Recycle

Today, a multitude of innovations have been developed to minimise the growing amount of waste materials, and recycling is one. The Oxford Dictionary defines recycling as "…the process of treating things that have already been used so that they can be used again".[33]

Auckland Council defines the recycling process as converting a used material into a new one. However, Hebel et al have simplified it in their book as a 'treatment process' which occurs in recycling that can be categorised into five different approaches, namely: densified, reconfigured, transformed, designed and cultivated.[34]

Densified Waste Material Process

One of the most effective methods of recycling is the densification of solid waste materials. Hebel et al described this process whereby machines facilitate the reshaping of waste materials according to

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[29] William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way we Make Things* (New York: North Point Press, 2002), 6.

[30] "Waste Reduction and Reuse", Clinton County Michigan, accessed April 12, 2022, Waste Reduction & Reuse | Clinton County, MI (clinton-county.org)

[31] Clinton County Michigan, "Waste Reduction and Reuse".

[32] *Rohani et al, Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill A case study based on HLC Ltd development in Auckland, 5.*

[33] "Recycling", Oxford Learners' Dictionaries, accessed April 12, 2022, recycling noun - Definition, pictures, pronunciation and usage notes | Oxford Advanced Learner's Dictionary at OxfordLearnersDictionaries.com

[34] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 5.*

a specific design through the use of compressing or vacuum-forming processes. In keeping with this, the compressing method encompasses any 'moulding' process. Hebel et al highlighted that, "The act of pressing stores energy in the system, resulting in a higher state of material properties."[35]

This process results in inherent changes in volume and functionality, altering the product potential. As an example, C&D waste material such as sawdust is a common waste material found in construction sites or wood manufacturing plants, yet, despite its potential, sawdust has been overlooked compared to other waste materials. Alan Booth, a South Island businessman, recycles sawdust using a briquette machine to produce Biobriq bricks as fuel in place of firewood.[36] Preventing this sawdust waste ending up at a waste facility is an innovation that has saved taxpayers up to $50,000 annually.[37]

Figure 2: Biobriq fire fuel

Figure 3: Biobriq (easy to stack)

Likewise, vacuum forming is a process where fabric is vacuumed onto a mould,[38] an invaluable process in any recycling treatment. Hebel et al created a prototype arch structure using the vacuum forming process. They vacuumed air out of a fabricated, airtight, foil tube bag, which was already shaped into an arch filled with empty, closed polyethylene terephthalate (PET) bottles.[39] Hebel et al explained that this process

> "…creates a lightweight and extremely efficient load-bearing element that can be used to create large-span spatial structures."[40]

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[35] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 33.*

[36] "The smart way to heat your home", BIOBRIQ, accessed April 12,2022, BIOBRIQ

[37] "How to get rid of a stockpile of sawdust?" Stuff, Koren Allpress, updated September 7, 2017, How do you get rid of a stockpile of sawdust? | Stuff.co.nz

[38] "What is Vacuum Forming?" British Plastics Federation, accessed April 12, 2022, What is Vacuum Forming? (bpf.co.uk)

[39] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 36.*

[40] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 36.*

Figure 4: Arch structure using empty plastic bottles

Reconfigured Waste Materials' Process

Hebel et al described the 're-configured' waste approach as a rearranging of the original form of any waste material either through sawing, breaking, shredding or grinding before being reprocessed to create a new product. An example of this is when fibre and waste chips are mixed with other materials to form new products. Hebel et al believed that

> "…the reconfiguration and rearrangement activate additional product characteristics and it implies the possibility to change form."[41]

An example of this is the Saveboard manufacturing processes. Saveboard, a manufacturing company, utilises all kinds of shredded packaging materials including plastic as its main source of raw materials in producing building panel boards. The shredded packaging is mixed with fibre and pressed at high temperatures to ensure complete binding to form sustainable building panels. Additionally, Saveboard provides recycle bags in which offcuts of their panels are packaged ready to

[41] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 63.*

be picked up to re-use as a resource in the production of the same commodity. This process clearly depicts an effective circular economy.[42]

Figure 7: Shredded materials

Figure 6: Variety of Saveboard samples

Figure 5: Installed Saveboard

Transformed Waste Materials' Process

This process entails the recycling of waste into a completely new form and original appearance. According to Hebel et al, the transformation of waste materials

> "…addresses the most extreme form of waste treatment: high-tech procedures that involve liquefying or gasification of the original material in order to create a new element with specific properties and resulting purposes."[43]

Hebel et al also implied that this process can be the approach for future waste management due to its capability to convert stubborn or toxic waste materials to newly constructed elements that are not only functional but better for the environment.[44] Tom van Soest, a Dutch designer and waste researcher who founded Stone Cycling, established a recycling technique where he transformed and produced a construction product called Waste Based Brick.[45] This brick is produced through the transformation of C&D waste such as glass, ceramics, stones and concrete. These are initially finely ground, then mixed together and poured into a mould, before being baked to produce new bricks. Similar to Saveboard, the binding of materials takes place organically. The product developed by Soest not only serves the purpose of waste reduction but also opens up the potential to engineer materials.[46]

[42] "Sustainable Building Materials", Saveboard, accessed April 12, 2022, https://www.saveboard.nz/

[43] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 95.*

[44] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 95.*

[45] "Tom van Soest Portfolio", Dutch Design Awards, accessed April 12, 2022, Portfolio - DDA (dutchdesignawards.nl)

[46] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 98.*

Figure 9: Waste-based bricks

Figure 8: A mixer used to make bricks

A vast quantity of construction materials can be generated through the 'transformed' waste materials approach such as Alusion-stabilised aluminium foam panels, CRT glass tiles, Byfusion bricks, GR green slate/cedar, Recy blocks, Nappy roofing, Tire veneer tiles, Blood brick, and Foamglass T4+.[47] Foamglass T4+ is a robust product, with good thermal properties; it is also known to be waterproof, pest/fire/moisture and chemical resistant, and offers ecological protection and a radon barrier.[48] All these characteristics are derived through and from employing the 'transformed' waste materials approach, perhaps justification for Hebel et al to label this approach as the future.

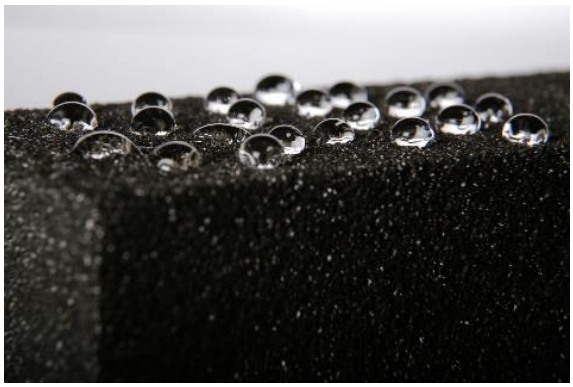

Figure 11: Water-resistant Foamglass

Figure 10: Foamglass

[47] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 106.*

[48] "Foamglass ready board T4+", Foamglass, updated August 1, 2021, PDS-READY BOARD T4Plus-INT-en.pdf

Designed Waste Materials' Process

Designed Waste Materials is a process that allows materials to have long and multiple life spans – life spans where the materials are constantly in the condition of re-adaption, reuse and recycling.[49] Hebel went further, emphasising that, through this waste process, materials keep

> "…their original form, properties, and material composition while their functions may change dramatically. Once such products have been used in the way and at the location for which they were originally destined, their particular character allows for yet another - second, third, even fourth - life cycle with different function. They might also be combined (without being mixed) with other materials into a heterogeneous condition of being, maintaining their ability to change their state again when required."[50]

This process was best showcased through the design of multiple plastic and glass bottles such as World Bottle, Jiikeen Cube, POLLI-Brick, UNITED BOTTLE and Water Brick.[51] The latter is intriguing based on its geometrical shape, which was purposefully designed so it can serve its second 'life's' purpose as a construction brick. The purposefully incorporated holes enable structural steel bars to be inserted for extra rigidity. Moreover, Water Brick was designed so it can be easily delivered, stored, handled, packed and used as a storage container, and it is designed to withstand force; for example, it doesn't break when dropped, even from a considerable height.

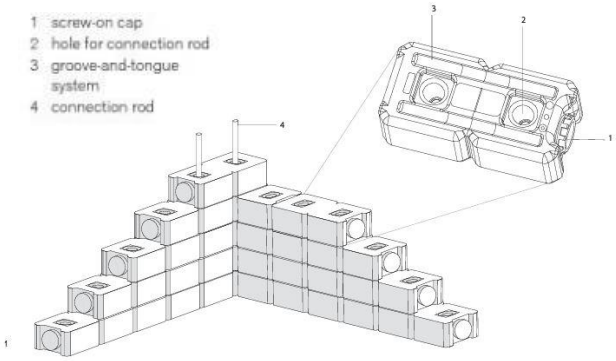

Figure 12: Water Brick containers used as a wall structure

Figure 13: Water Brick containers

[49] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 127.*

[50] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 128.*

[51] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 129.*

Organic Waste Design Process

Today, young designers and innovators aspire to fabricate innovations and creations incorporating natural resources that will facilitate the organic decomposition of a product when no longer in use. This natural occurrence, called Organic Waste Design, concentrates entirely on organic waste materials as its main input resource.[52] Designer Julian Lechner made a breakthrough discovery with the idea of making an Ex-Presso cup and saucer set out of organic coffee grind waste collected from local cafés. He pressed and moulded the grinds as per his cup and saucer design, with the addition of melted sugar as a bonding ingredient. The release of an aroma, which further enhances the flavour as the set starts to dissolve, is an added bonus while drinking coffee from this cup.[53]

Figure 14: Saucer set made out of coffee grinds

Cultivated Waste Materials' Process

This process consists of a gradual layering of microelements processed to cultivate a much larger-sized product, and Hebel et al considered it as a 'cutting edge' approach in the building industry.[54] In this scenario, microelements are considered waste that can be cultivated according to preferred size and volume in the building sectors. Additionally, they can be composted without any harmful environmental effects when discarded.[55] A group of innovators called the Ecovative developed a Tiny Mushroom House made of fungoid elements, which transitioned into developing building fungoid panels with the assistance of architects.[56] They proudly and clearly emphasised that they "…didn't just build a tiny house, we grew it".[57]

[52] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 146.*

[53] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 146.*

[54] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 151.*

[55] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 153.*

[56] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 158.*

[57] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 158.*

Figure 15: Material cultivated from fungoid elements

This method can also be implemented in the manufacturing of other materials to function as an immune system. Biologist Henk M. Jonkers pioneered the solution to a devastating and cancerous problem in the building sector of broken and cracked concrete structures. He discovered that by adding a particular bacterium (one that requires contact with water and air through cracks to activate) to the concrete mix, the bacteria then produce calcium between cracks, sealing off concrete crack defects over time.[58]

Recover

Auckland Council refers to the term 'recover' in waste management as a collection of waste material that is not fit for reuse or recycling. Instead, it is incinerated to generate energy for manufacturing or HVAC heating systems. For instance, wooden off-cuts that cannot be recycled or reused can be directly burned as fuel to produce energy in the concrete manufacturing process.[59]

However, this method is strongly opposed by Zero Waste Network (ZNT), a part of the Community Enterprise Network Trust which is focused on providing support to participating sectors in relation to waste minimisation goals.[60] Zero Waste Network considers "…waste-to-energy incineration as an unacceptable option for waste management".[61]

Incinerator plants today are much cleaner but remain unsustainable, because these plants continue to release deleterious chemical gases like mercury, dioxins and cadmium, posing a major health risk.

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[58] Hebel et al, *Building from Waste: recovered materials in architecture and construction, 156.*

[59] *Rohani et al, Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill A case study based on HLC Ltd development in Auckland, 5.*

[60] "Our Mission, Our Vision, Our story, Our member", Zero Waste Network, accessed April 12,2022, About us | Zero Waste Network New Zealand

[61] "Our position", Zero Waste Network, accessed April 12, 2022, Waste to Energy Incineration | Zero Waste Network New Zealand

Equally important, they are also a major contributing factor to greenhouse gas emissions, due to the sheer amount of carbon dioxide they emit.[62]

Residual Disposal

Likewise, this waste treatment is considered a waste material graveyard, a resting place for any waste materials which are no longer able to be reused, recycled or recovered.[63] Landfills are buried when they reach their capacity; therefore, this method still carries serious environmental and public health risks since these waste materials may contain toxic substances that can seep through into waterways.[64] For this reason, Auckland Council is determined to ensure that the linear economy becomes obsolete[65] and instead, it promotes the idea of a circular economy, with the aim of making landfills obsolete.[66]

Waste Treatment through Design

This section mainly deals with ideas of improving design and building techniques to improve the construction process and the disassembling of building elements at the end of a building's life.

Deconstruction – Designed to Disassemble

Multiple findings define the term deconstruction and its application in the building industry. Researcher Paul Frishman described deconstruction as a

> "…relatively recent practice in which buildings are carefully dismantled to salvage components for reuse and recycling."[67]

[62] Zero Waste Network, "Our position".

[63] J. Brennan, G. Ding, C.R Wonschik and K. Vessalas, "A Closed-loop System of Construction and Demolition Waste Recycle", (Dissertations: University of Technology Sydney, 2014), 500, Brennan et al Paper.pdf (uts.edu.au)

[64] "Waste generation and disposal in New Zealand", New Zealand Government, Ministry for the Environment, updated September 9, 2021, Waste generation and disposal in New Zealand | Ministry for the Environment

[65] *Rohani et al, Cost Benefit Analysis of Construction and Demolition Waste Diversion from Landfill A case study based on HLC Ltd development in Auckland, 5.*

[66] Zero Waste, "Zero Waste Network".

[67] Paul Frishman, *Building Deconstruction,* December 13, 2004,1, BUILDING DECONSTRUCTION

whereas J.P. and A.M. Couto elaborated the term by stating in their study that

> "Deconstruction is the process of taking a building or structure apart, selectively dismantling and removing materials before the structure is demolished, or avoiding demolition altogether, and disassembling the entire structure, in the reverse order in which it was constructed."[68]

It is proven that deconstruction is a more sustainable way of recovering C&D waste than being thrown into dumpsters in the demolition process. Deconstruction reduces C&D waste generation, opens economic opportunities, and alternatively reduces or averts the need to extract raw resources.[69] However, a deconstruction project typically takes longer than a demolition project. Since every building component must be carefully removed or packed with minimal damage and ready for transportation,[70] it is crucial to implement ideas and concepts around minimising the time required for deconstruction activities.

Prefabricated Elements

A commercial or a residential building is typically seen as one whole geometrical block, even though it is understood that it is made up of different parts that have been installed or constructed by on-site professionals who are specialised and assigned for each part of the building.[71] Timber structures, drainage piping, tiles and aluminum flashings, which are measured, cut, drilled, hammered and retrimmed for a perfect fit, are among the individual units that make up the 'blocks'. These individual units can be considered as on-site fabrication activities.[72] This procedure is slower than employing prefabricated modular construction techniques; it generates more waste, and slows the deconstruction procedures undertaken at the end of the lifespan of a building.[73] Consequently, it is vital to change structural design and construction practices in building.

However, if building components are delivered to the site as an assembly of parts (modulars) instead of as individual parts, it will speed up the project construction and minimise the creation of C&D waste on site. It will also reduce the time taken for deconstruction at the end of the lifespan of that

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[68] J.P. Couto and A.M Couto, "Reason to consider the deconstruction process as an important practice to sustainable construction", (Dissertations: University of Minho Guimaraes), 2, Microsoft Word - sb07_deconstruction_fullpaper_1__submetido_R.doc (eurogypsum.org)

[69] Paul Frishman, *Building Deconstruction*, 1.

[70] "Deconstruction: a blueprint for zero waste", Auckland Council, Our Auckland, updated October 6, 2020, Deconstruction: a blueprint for zero waste - OurAuckland (aucklandcouncil.govt.nz)

[71] "How the construction industry works?" Go Construct, accessed April 12, 2022, How The Construction Industry Works [Complete Guide] | Go Construct

[72] Go Construct, "How the construction industry works?".

[73] Go Construct, "How the construction industry works?".

building, since the disassembly will be taking away assemblies of parts rather than individual pieces one at the time.

One building successfully constructed using a prefabrication assembly of parts is the NEST (Next Evolution in Sustainable Building Technologies) "Urban Mining & Recycling" unit building. Located in Empa, Dubendorf, Switzerland, it was designed by Hebel and Heisel, authors of *Building from Waste*, together with Werner Sobek. As well as using compostable, reusable and recyclable materials in this building, the designers implemented prefabricated assembly of parts and prioritised the utilisation of screw fixings rather than nails to construct the building. The building elements were prefabricated off site into multiple pods; each pod represented its functional space. For example, the kitchen, bathroom and hallway pods, etc, were placed and aligned together like Lego, using cranes to form the NEST building. This building design allows deconstruction procedures at its end of life to be sustainable and quicker and for salvaged materials to remain in their near new original form, ensuring salvaged materials will be valuable and acceptable to be reused and recycled.[74]

Material Selection

To enhance the deconstruction procedure, the client's selection of materials for a project is critical.[75] Some building elements require the application of a chemical bonding product to fix assemblies onto a building, which can be challenging to remove. For example, using screws to assemble a timber framing is more straightforward to disassemble without breaking the timber than using wood glue in a timber framing. Therefore, if the client is aware of such issues in the early stage of design, then material selection can be verified and included in the design.[76]

Architectural Precedents

One of the greatest ways of communicating is storytelling, a method that has been used since the Stone Age, either orally or through cave paintings. Today, there are different ways and methods to communicate, including but not limited to audio-visual media, written language and sign language.[77] Architects, however, tell their stories through buildings, with architectural designs that are often

[74] Stephen Kalin, "Building with waste and recycled material", Phys Org, updated February 9, 2018, https://phys.org/news/2018-02-recycled-material.html

[75] Nima Norouzi, Maryam Shabak, Mohamed Rashid Bin Embi and Tareef Hayat Khan, "The architect, the client and effective communication in architectural design practice", Science Direct, (2014), 636, The Architect, the Client and Effective Communication in Architectural Design Practice (sciencedirectassets.com)

[76] Nima Norouzi, Maryam Shabak, Mohamed Rashid Bin Embi and Tareef Hayat Khan, "The architect, the client and effective communication in architectural design practice", 636.

[77] "Every design tells a story", Tsaua, updated December 4, 2018, Every Design Tells a Story - TSA Architects (tsa-usa.com)

experienced through the five senses. A visually impaired person can navigate through building spaces, not only by hearing and touching, but also through the sense of smell. The Center for the Blind and Visually Impaired, designed by Taller de Arquitectura-Mauricio Rocha in Mexico, uses a channel of running water along an outdoor corridor floor as an audio guiding element. As well, various wall textures for different building blocks act as tactile maps, and different fragrant plants enhance navigation.[78] Architects are capable of telling a story through their building designs, despite inherent limitations.

Ningbo Museum

Ningbo Museum, a remarkable public building designed by Wang Shu and his wife, Lu Wenyu, of Amateur Architecture Studio, is a good example of reusing C&D, and earned them the Pritzker Prize in 2012.[79] The building, inaugurated in 2008, is located on a site where 30 villages were demolished in Ningbo city in Zhejiang province, China. The architects integrated salvaged tiles and bricks (some are aged over 1000 years) from demolished villages in the area to create a distinctive façade and cubical building.[80] In addition, a concrete wall with a bamboo textured finish, which is seen from the façade at some parts of the upper corners of the building, was purposefully incorporated into the design as a form of display of the Chinese heritage.[81] In an interview with Dezeen, Shu said that

Figure 17: Ningbo Museum is built on the site of a demolished village

Figure 16: 'Wapan' technique

[78] "Center for the Blind and Visually Impaired/Taller de Arquitectura-Mauricio Rocha", Arch Daily, updated August 11, 2011, Center for the Blind and Visually Impaired / Taller de Arquitectura-Mauricio Rocha | ArchDaily

[79] Benedict Hobson, "Wang Shu's Ningbo Museum built from the remains of demolished villages", Dezeen, updated August 18, 2016, Video: Wang Shu on Amateur Architecture Studio's Ningbo Museum (dezeen.com)

[80] Benedict Hobson, "Wang Shu's Ningbo Museum built from the remains of demolished villages".

[81] Benedict Hobson, "Wang Shu's Ningbo Museum built from the remains of demolished villages".

there was a huge amount of beautiful, demolished materials across the entire site. Hence, he wanted to create something as a token of remembrance for the locals,[82] to retain part of the identity of the demolished villages, and to preserve Chinese culture.

Furthermore, Shu worked closely with local craftsmen to incorporate the traditional 'wapan' method where elements of various dimensions are overlaid to form rigid structures.[83] He believed that, "Only people who understand the nature of the materials can make art using the materials."[84] Therefore, local craftsmen laid tiles and bricks randomly and organically as seemed fit in their place[85] to construct an iconic building that promotes the identity and history of the area, and is sustainable by unlocking the potential of reusing C&D waste.[86] Evan Chakroff, a designer and critic, defined Shu's work:

> "…represents a vital and promising path forward that does not deny the past...a way forward for Chinese architecture that doesn't rely solely on flashy renderings and iconic forms, but that can retain those essential qualities of the historical fabric that make China's ancient cities so appealing, those qualities most endangered and vanishing rapidly in the rush of modernization."[87]

Chakroff highlighted that Shu's broad knowledge of the materials and building techniques was the main driving factor in the Ningbo Museum project. Thus, this project serves as an economic model, cultural heritage, and an environmentally driven building story which demonstrates one of the 5Rs – the r*ecycling* approach – by integrating recycled tiles and bricks salvaged from their context as significant structural elements.

[82] Benedict Hobson, "Wang Shu's Ningbo Museum built from the remains of demolished villages".

[83] Benedict Hobson, "Wang Shu's Ningbo Museum built from the remains of demolished villages".

[84] "Ningbo Museum by Wang Shu: The Recycled Building," Rethinking the Future, accessed April 12, 2022, Ningbo Museum by Wang Shu: The Recycled Building - RTF | Rethinking The Future (re-thinkingthefuture.com)

[85] Evan Chakroff, "Recasting History: The Ningbo Historic Museum", *JSTOR*, no 24 (2012), 57, https://www.jstor.org/stable/pdf/41765469.pdf?refreqid=excelsior%3Ada981bcb158811b91aa16225ddc0e96b&ab_segments=&origin=&acceptTC=1

[86] Evan Chakroff, "Recasting History: The Ningbo Historic Museum", 57.

[87] Evan Chakroff, "Recasting History: The Ningbo Historic Museum", 62.

The Slaughterhouse

A good example of re-use, The Slaughterhouse was built in 1933 as a slaughterhouse to increase the supply of meat to cater for a growing Shanghai city.[88] The site's original building was designed by Shanghai's Public Works Department in the 1920s, before being rebuilt and becoming a historical architectural landmark for Shanghai.[89] Balfours, a British architect, integrated a mass of concrete in the design, which reflected the modernist architecture style at the time and symbolised the growth of Shanghai.[90]

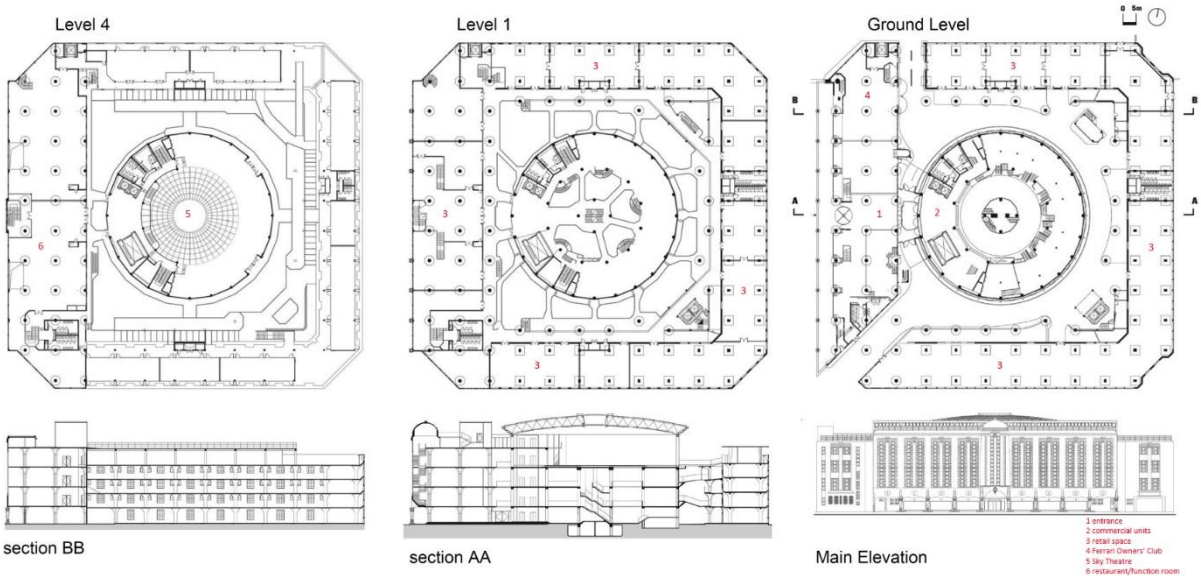

Figure 18: The Slaughterhouse - Plans, sections and main elevation

Apart from its architectural qualities that are displayed and experienced, what stand out are the variations in its functionality over a period of time. From a slaughterhouse, to a cold food storage and drug manufacturing facility, today it is known as a cultural quarter.[91] The slaughtering process ended in the 1960s,[92] and the building was reused as a frozen food and drug facility from the 1970s to the early 2000s.[93] Then it became a ghostly, silent space visited by tourists and locals for leisure.[94]

[88] Austin Williams, "From the slaughter to laughter: the renovation of a slaughterhouse in Shanghai by IPPR", The Architectural Review, updated October 22, 2018, From slaughter to laughter: the renovation of a slaughterhouse in Shanghai by IPPR - Architectural Review (architectural-review.com)

[89] Austin Williams, "From the slaughter to laughter: the renovation of a slaughterhouse in Shanghai by IPPR".

[90] Monica Liau, "1933: The Slaughterhouse of Shanghai", Culture Trip, updated December 6, 2017, 1933: The Slaughterhouse of Shanghai (theculturetrip.com)

[91] Austin Williams, "From the slaughter to laughter: the renovation of a slaughterhouse in Shanghai by IPPR".

[92] Monica Liau, "1933: The Slaughterhouse of Shanghai".

[93] Emily Wetzki, "A Brief History of Shanghai's Old Slaughterhouse 1933" That's Magazine, updated July 3, 2014, A Brief History of Shanghai's Old Slaughterhouse 1933 – That's Shanghai (thatsmags.com)

[94] Austin Williams, "From the slaughter to laughter: the renovation of a slaughterhouse in Shanghai by IPPR".

However, by 2008 it was restored to its former glory by Shanghai Engineering Design and Research Institute (IPPR) with the guidance of architect Zhao Chongxin, and became a popular cultural quarter.[95] The structure was repaired, the water tower was converted into a sky theatre, the carcass storage rooms were turned into restaurants and function spaces, while the ground floor spaces were populated with crafts shops and cafés. The building became an attraction for tourists, filmmakers and photographers.

Figure 20: Core view

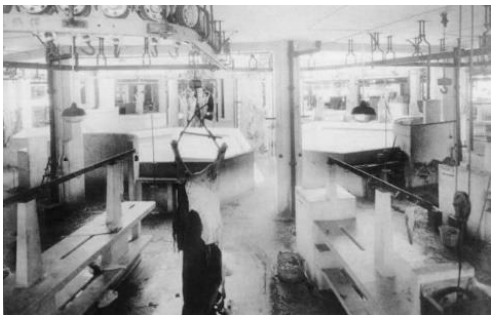

Figure 19: The Slaughterhouse in its early days of operation (x2)

Thus far, the Slaughterhouse has been reused three times, requiring minimal restorations while still serving its purpose and living up to its full potential. It may be reused multiple times again, with the proviso that it continues to be well preserved and make history that will be told in the future.

The Flagship Education Centre by Sustainable Coastline

Environmental issues have seen the building design industry implement and develop strategies to improve building performance and lessen environmental degradation around the world. This is based on multiple design principles, one of which is the Living Building Challenge (LBC).[96] The challenge consists of seven design principles: beauty, materials, health and happiness, energy, water, equity and place. Through the building certification approach, The Flagship Education Centre

[95] Austin Williams, "From the slaughter to laughter: the renovation of a slaughterhouse in Shanghai by IPPR".

[96] "The Top 6 Sustainable Architecture Strategies for Public Building Design" HMC Architects, updated October 3, 2018, The Top 6 Sustainable Architecture Strategies for Public Building Design | Thought Leadership | HMC Architects

building was conceptualised by Sustainable Coastlines, which is the second LBC in New Zealand and the first in Auckland.

The LBC's Place Petal is about re-establishing a healthy connection between the built environment, the community and nature.[97] The water petal is a reminder of the value of water and ways to apply water preservation processes. An example of this is to redirect unclean water for other uses rather than sending it straight to sewage.[98] Energy petal, on the other hand, deals with implementing new ideas for harvesting and harnessing renewable energy as a top priority.[99] Health and happiness petal emphasises the importance of the well-being of humans and the wider eco-system alike, through building performance within indoor and outdoor spaces.[100] Material petal plays a part in every building design as it raises awareness around the impact of building materials on the environment.[101] Equity petal promotes and elevates a more meaningful, well-balanced programme that comprises the community.[102] Lastly, the beauty petal is simply that – to showcase the beauty and connection of the building with its surroundings.[103]

Figure 22: Shipping containers donated and utilised as building elements

Figure 21: Main outdoor corridor space

[97] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, (2019), 28, https://are320k.files.wordpress.com/2019/05/living-building-challenge-4.0.pdf

[98] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, 36.

[99] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, 41.

[100] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, 45.

[101] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, 50.

[102] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, 58.

[103] International Living Future Institute, *Living Building Challenge 4.0: A Visionary Path to a Regenerative Future*, 64.

Health and Happiness

The overall design of the Flagship building complies with the LBC principles. The centre was constructed as a headquarters and to serve as an event venue and educational centre. It is built out of non-toxic building materials, and offers non-treated yet safe drinking water. The incorporation of a green roof eliminates nitrogen oxide and the use of specific plants contributes to better air quality. This is further reinforced by establishing smoking restriction zones. Wastewater is used to water the plants.[104]

Beauty

The significant architectural design of the building allows elements that represent Auckland; that is, an open layout design allows easy air circulation within its spaces, the exhibition of recycled materials signifies the urban area of Auckland, and an array of plants on site emphasises the beautiful nature of Auckland.[105]

Material

In addition, 85% of materials used in the building are recycled, repurposed and reused C&D waste. The steel structure, the glass canopy, and the decking were made by inmates of Paremoremo Prison as part of the prison upskilling programme. As well, part of the prison wing was renovated and some of its structural elements were reused for the Flagship building. The modular containers on site that are utilised as structural and functional spaces were donated by Samsung and were formerly used in its campaigns. The sustainable roofing materials were donated by Nuralite, and railway sleepers were reused for most of the decking structure. The interior walls and flooring and the exterior cladding section of the building including the planters were all crafted from wood salvaged from C&D sites, while the non-toxic bricks were made on a machine that has been used for many years. From a sustainability perspective, the most impressive aspect of this building is that it was constructed and designed for disassembling so it can be deconstructed quickly and reused or repurposed elsewhere.[106]

[104] "Creating our living building", Sustainable Coastlines, accessed April 12, 2022, Living Building Challenge | Sustainable Coastlines

[105] Sustainable Coastlines, "Creating our living building".

[106] Sustainable Coastlines, "Creating our living building".

Figure 25: Glass and joinery from Paremoremo Prison in the deconstructed building

Figure 23: Tiles and wooden elements were salvaged from C&D sites

Figure 24: Decking materials are made out of salvaged waste materials

Place

The building is located on the edge of Silo Park, with good foot traffic, with professionals, locals, tourists, restaurants and parks nearby all adding life to the area. Choosing this particular location was a strategic approach as it is on a car parking lot, which eliminates some parking spaces in line with the goal of promoting a zero-emission philosophy.[107]

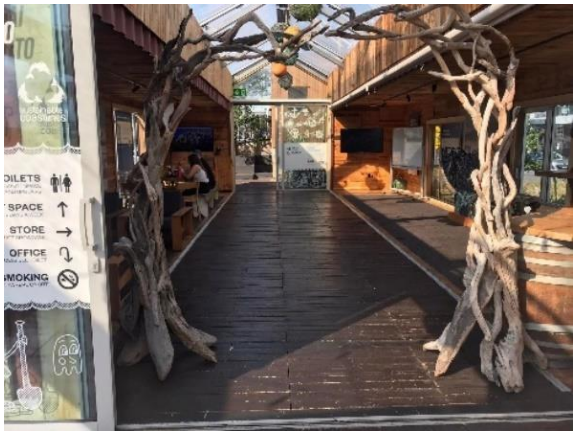

Figure 27: Interior linings and flooring made of salvaged timbers

Figure 26: A storage space made of shipping containers

Equity

This petal is reflected on the Flagship as it serves as a community hub and event venue: a place for all, where they can access information and participate in environmental activities within the local community.[108]

[107] Sustainable Coastlines, "Creating our living building".

[108] Sustainable Coastlines, "Creating our living building".

Energy

The building is run entirely by renewable solar energy sources and, therefore, is self-sustainable. Vector donated the system and installed it to power up the entire building. Moreover, the inclusion of double-glazed joinery in the building reduces the energy consumption for heating and cooling.[109]

Figure 29: The building is self-sustaining for energy - solar panels face northwards to maximise sun exposure

Figure 28: Water tanks built onsite to collect water

Water

Rainwater is collected from the roof and funnelled into water storage tanks before being pumped into a four-phase filtration system, after which the filtered water is then ready for human consumption. In addition, wastewater from kitchen and bathroom sinks is collected and treated on site and pumped back for watering plants. Lastly, human waste is processed and treated on site using aerobic bacteria introduced to break down excrement. Ultimately, no waste is sent off-site.[110]

The Athletic Centre

This precedent is useful to the project because of its programme and relationship to its environment, as well as its construction methodology. Designed by Studio Saxe and completed in 2019 to be a public fitness village in Nosara, Guanacaste, Costa Rica, it is a remarkable piece of architecture among existing trees. Paula Pintos, a curator, in an Arch Daily article, highlighted that the design concept is a clever way

> "…of adapting complex and diverse program of spaces within the existing framework of trees and wildlife of the site. Human activity is intended to co-exist in a symbolic relationship with the natural world in order to accentuate the path towards wellbeing."[111]

[109] Sustainable Coastlines, "Creating our living building".

[110] Sustainable Coastlines, "Creating our living building".

[111] "Costa Rica Athletic Center/Studio Saxe", Arch Daily, accessed April 12, 2022, Costa Rica Athletic Center / Studio Saxe | ArchDaily

The athletics complex utilises studio rooms for multiple indoor games, fitness classes, therapies and sports retail shops, all of which are enveloped by greenery and nature. The integration of lightweight, overhanging roof and steel structures, clad with teak and filled with glass walls, evokes transparency, helping it sit among the shady trees.

Figure 30: Plan layout, interior(x2) and exterior spaces(x3)

Additionally, Studio Axe was able to arrange prefabrication of the building elements elsewhere and have them delivered in modules, then placed carefully into pre-determined gaps between existing trees, preserving the tree roots. The entire process precluded any unnecessary site clearing of existing trees and, instead, was broken down into smaller building sections connected by bridges and footpaths.[112]

In addition, the orientation of the building was designed to shelter interior spaces from the sun while ensuring natural ventilation. It was also placed to maximise rain catchment to be self-

[112] Studio Saxe, *The Athletic Center At The Gilded Iguana* (January 2020), 3, StudioSaxe_TheAthleticCenter_PressRelease_ENG.pdf

sustaining for water. The layout of the complex nurtures the connection between occupants and nature while promoting environmental awareness.[113]

Tectonic Architecture

In order to better understand the application of C&D waste, it is vital to explore Tectonic Architecture. Scholar Robert Maulden depicted Tectonics in Architecture as

> "the science or art of construction, both in relation to use and artistic design. It refers not just to the activity of making the materially requisite construction that answers certain needs, but rather to the activity that raises this construction to an art form. It is transcending the banality of mere building by the modeling of a physical thing which reveals a conscious attempt by the architect to tell a story."[114]

This statement aligns with Hoda Al-Alwan's and Yusur B Mahood's online article highlighting

> "Tectonics is the essence of architecture that deals with the aesthetic aspects of structure, construction, and materials. It tends to consider the handicrafts, details, and joints as an essential part of architectural practice and as an important means of showing cultural expression by using the simplest techniques and materials. Tectonics creates emotional interaction between people, nature, and culture by its dependence on the human ability to understand the inspirational relations between the elements of the building."[115]

The definition of tectonic architecture as defined above is best represented by Gregor Kregar's artistic and creative timber sculptures on Waiheke Island[116], and through The Metropol Parasol in Seville, Spain, by J. Mayer H. Architecture.[117]

Kregar is a Slovenian artist who lives and works in Auckland, exhibiting his artwork across New Zealand.[118] His creation, the Pavilion Structure, won the people's choice award in the 2013 Sculpture On The Gulf exhibition. Created from 11 tonnes of recycled timber, this 11-metre x 11-metre x 9-metre architectural pavilion sculpture was intended to serve the purposes of shelter and leisure, a

[113] Studio Saxe, *The Athletic Center At The Gilded Iguana*, 7.

[114] Robert Maulden, Tectonic in Architecture: From the Physical to the Meta-Physical", (Master thesis, Massachusetts Institute of Technology, 1986), 3, 15434951-MIT (1).pdf

[115] Hoda Al-Alwan and Yusur B Mahmood, " The Connotation of Tectonics in Architectural Theory", IOP (2020), pdf (iop.org)

[116] "Pavilion Structure", Gregor Kregar, accessed April 12, 2022, Pavilion Structure | Gregor Kregar

[117] Amy Frearson, "Metropol Parasol by J Mayer H", Dezeen, updated April 26, 2011, Metropol Parasol by J Mayer H | Dezeen

[118] "The Glass Room, 2016", Sculpture on the gulf, accessed April 12, 2022, Gregor Kregar - Sculpture On The Gulf (sotg.nz)

place where visitors can sit and unwind, or walk through. Either way, one can experience the artistic connection between the timbers and space.[119]

Figure 31: Gregor Kregar's recycled timber pavilion (x4)

The Metropol Parasol is the largest structure to be constructed primarily using chemical elements such as glue to assemble the building structure.

Figure 32: Glued timber structure (x3)

The structure is made up of laminated timber, concrete and steel, which were fabricated off-site and assembled together on site, and consists of over 40,000 connection points. The structure has a

[119] Gregor Kregar, "Pavilion Structure".

waffle-grid interlocking system which in itself is an embellishment – making it a significant landmark and an important piece of architecture in Seville.

The Proposed Project

Raising awareness can be challenging since the main goal is around people's consciousness and behaviours – it's about convincing them of a concept or an issue. In this project, the concept is around ensuring C&D waste is seen as having equal value to when it was first manufactured. This campaign for waste reduction will be showcased in the heart of one of Auckland's vibrant and diverse communities, Manukau. The intention is to draw attention to waste reduction issues and to tackle the community's obesity and social problems. Hence, this project will utilise Brown Butterbean Motivational headquarters, together with a Wood C&D Waste Hub.

Brown Butterbean Motivational (BBM)

"Everything we provide in order to make a difference in the community is free" is the approach of BBM, which aims to encourage those who feel neglected, hopeless and despised. BBM offers a chance of a fresh start, more specifically targeting health and overall well-being.[120] BBM was founded by David Letele, who originally set it up as a boot camp in 2015 to help those who were overweight and obese across Auckland.[121] In 2019, at Eden Park, BBM held the world's biggest boot camp for about 2000 people.[122] At present, BBM operates successful food banks, community gyms and kitchens. On top of this, BBM is planning to expand its programme by organising/facilitating free clinics, kids' zones, a food bank and youth career development courses, and Letele is looking for a community centre where everyone is welcome.

Construction and Demolition Waste Hub

The inclusion of a Wood C&D Waste Hub aligns with the BBM programme. The aim of the hub is to process only wooden C&D waste to be recycled and add value, prepared and ready for its next life. Members of the public and professionals can also source materials, and learn and exchange techniques of wood craftsmanship. The proposed principal design focus of the centre is to bring people and communities together, connect people to nature, promote well-being and, above all, raise awareness of waste management issues.

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[120] "Discover our Story", The Brown Butterbean Programme, accessed April 12, 2022, Our Story - The BBM Program

[121] Steve Kilgallon, "Punching above his weight: the remarkable story of Dave Letele", Stuff, updated January 9, 2022, Punching above his weight: the remarkable story of Dave Letele | Stuff.co.nz

[122] Chris McKeen, "Fitness motivator Dave Letele plans world's biggest bootcamp for Eden Park", Stuff, updated January 15, 2019, Fitness motivator Dave Letele plans world's biggest bootcamp for Eden Park | Stuff.co.nz

Design Process

The design process was systematically arranged through C&D site investigation, informal discussions with Letele, modelling, site analysis and integration of C&D waste in the design.

Informal Conversation

One of the most important undertakings in the design process development of the programme was the informal conversation with the founder of BBM, held at the current location in Manukau City Centre. Letele envisioned a safe place where families from the community could attend and participate in one of the free-of-charge BBM programmes which include bootcamps, a gym, short courses, a public kitchen, a food bank storage/distribution space, a childcare unit and office spaces.

Construction and Demolition Site Investigation

It is vital to understand what C&D waste can be obtained on site located within the 20-kilometre radius from the selected programme site, hence a site investigation was conducted to review what C&D waste material is, in fact, available. The materials found were from construction sites (Voco Hotel, Hobson Apartment Penthouse, and Unitec building 108), demolition sites (Unitec building 202, The Workshop – Mt Wellington), and demolition yards (Ward Demolition, Heards Landscape Supplies Ltd), and are listed on *Table 1* below:

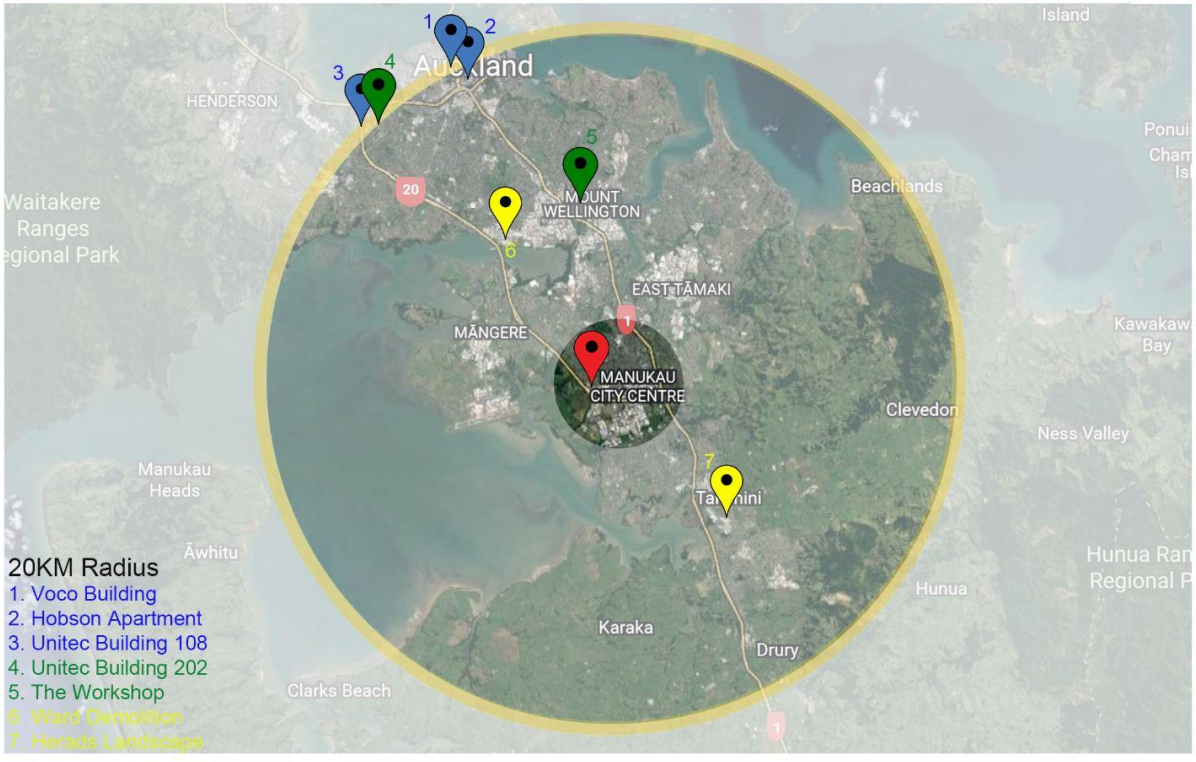


Figure 33: C&D waste site investigation map

Table 1 Site	Project/Firm	C&D Waste	Comment
Construction	Voco Building (8 Customs Street East, Auckland CBD)	Timber Plywood Packaging pallets Off-cuts Broken scaffolding blocks Cardboard Concrete rubble	I visited the site towards the end of the construction of this project and these materials were scattered all around the site. Two bins were full of timber off-cuts and general packaging materials.
	Hobson Apartment Penthouse (196 Hobson Street, Auckland CBD)	Timber Plywood Off-cuts Aluminum extrusions	This project utilised timber structure and aluminum cladding entirely on the penthouse.
	Unitec building 108 (139 Carrington Road, Mount Albert, Auckland)	Timber Off-cuts Gib board Metals	Unfit elements were taken out and replaced with new ones. These include structural elements.
Demolition	Unitec building 202 (139 Carrington Road, Mount Albert, Auckland)	Concrete rubble Soil Steel	Laminated timber structure and rubble were taken to Enviro to be reprocessed. Steel materials were all taken to Sims to be recycled.
	The Workshop – Mt Wellington (10-12 Harrison Road, Mt Wellington)	Soil & rocks Structural steel Concrete rubble Brick tiles Asphalt	Rocks & soil are re-used in the new project. The rubble is processed on site and re-used, and the rest are taken out to the yard or to be recycled.
Yards	Ward Demolition (13/17 Miami Parade, Onehunga, Auckland)	Fittings Joinery and doors Concrete rubble Flooring materials Assorted furniture Rubble	All materials are sold directly from their yards and some are processed in the yard. Rubble is crushed and sold. Metals are pressed and sent to the scrap yard.
	Heards Landscape Supplies Ltd (75 Boundary Road, Papakura, Auckland)	Untreated timber Concrete rubble Concrete tiles	Mostly accepts untreated timber so it can be mulched and sold.

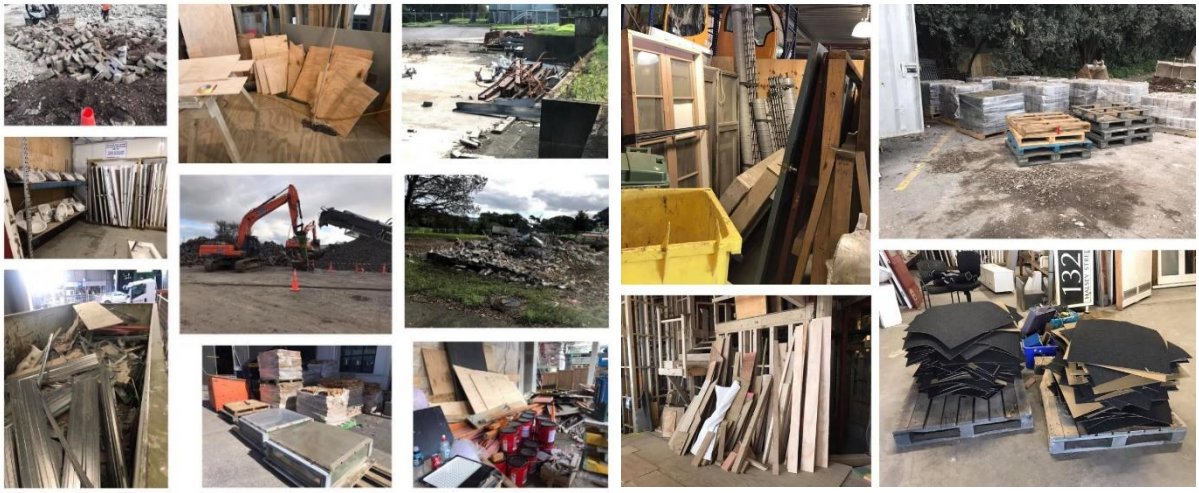


Figure 36: C&D waste materials at the sites visited

Modelling

To better visualise the concept design, modelling was carried out: firstly, by crafting three coffee tables using three different types of fixings (using only a drill, a tie and clamps) on each one, which are mechanical, chemical and geometrical/lashing. This method helped with visualising how materials would be assembled and installed onto the proposed building. Secondly, remodelling the actual carpark building by obtaining plans from the council, multiple site visits to the carpark location, and transferring them into Revit modelling software, made it easier to develop the design. Lastly, web browsing in search of ideas and information had a significant impact on finalising the proposed design.

Figure 39: Three different table frames with three different types of assembly (Chemical-wood glue, Lashing-string, Mechanical-screws)

Figure 42: Lashing patterns

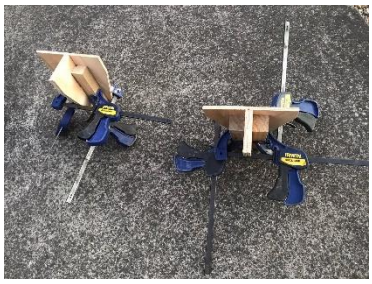


Figure 40: Clamping wood together

Figure 41: The only tools used for assemblies

Site Selection

Manukau City Area was once known as Woodside, settled and cultivated by Nga Riki, a sub-tribe of Nga Oho occupying the Papakura to Otahuhu region. This area was then further developed by European settlers as dairy and crop farms until the 1950s. By 1965, Manurewa borough and Manukau county united to form Manukau City. The region is home to 165 different ethnic groups, making it New Zealand's most culturally diverse urban area.[123]

Manukau City, South Auckland, is the location of the proposed project. This sprawling city has a strong sense of community, and it is currently dealing with the social issue of obesity. Within this specified area, the project will re-purpose Ronwood Carpark, a building of eight floors – crafting it into a BBM headquarters and a C&D waste hub. This site has the potential to promote the project's environmental focus, together with the prospect of improving overall well-being and bringing together a vibrant community.

Prospective Sites

During the development of this research project, one significant desired outcome was to be able to give back to the community, regardless of location. In this instance, the South Auckland area was ideal, and BBM was already situated in the Manukau City area. The decision around the location was influenced by the statistical finding that the majority of Maori and Pacific Islanders with obesity reside in the South Auckland area. In fact, the health ministry highlighted that one in three New Zealanders aged 15 and over are categorised as obese – 71.3% Pacific Islanders, 50.8% Maori, 32.9% European/Other, and 18.5% Asian.[124] Correspondingly, South Auckland is home to the largest

[123] "South Auckland", New Zealand Government, Te Ara, accessed April 12, 2022, South Auckland – Te Ara Encyclopedia of New Zealand

[124] "Obesity statistics", New Zealand Government, Ministry of Health, accessed April 12, 2022, Obesity statistics | Ministry of Health NZ

number of Pacific Islanders living in New Zealand.[125] With all these factors considered, the site investigation was carried out around the Manukau City Centre, specifically because it is viewed as the main centre for South Auckland, and it is also where the current BBM headquarters are located.

Figure 43: Site analysis layout

The first site found was an empty car park on Great South Road between Carl's Jr and Wendy's that was to be developed as a new build; however, the site was not suitable as it is located between the two fast-food chains. Next, an old warehouse building located on the same road opposite Rainbow's End was considered as it has the potential to be renovated. It was discounted as an option when renovations started to transform it into a church. After some time exploring the local area, the Ronwood Carpark building located at 2 Davies Avenue, Manukau City Centre, became the top contender. This carpark building has eight floors including the ground floor of 680 parking spaces; it was designed by Babbage, built in 2012, and is owned and operated by Auckland Transport (AT) entirely as an investment, with the intent to enrich the community.[126] However, this $14million investment was a deemed a disaster as it did not bring in even half of its build costs, according to a *New Zealand Herald* article by Bernard Orsman in 2012. The building is barely occupied so the parking rate was dropped from $3 to $1 to attract more vehicles to the building, which was

[125] "Pacific Auckland", Auckland Council, Auckland Plan 2050, accessed April 12, 2022, Pacific Auckland (aucklandcouncil.govt.nz)

[126] Bernard Orsman, "$14m empty carpark-that you paid for", Stuff, updated November 13, 2012, $14m empty carpark - that you paid for - NZ Herald

unsuccessful.[127] Many critics voiced that the building is a complete failure and a waste of taxpayers' money.[128]

Figure 44: Ronwood carpark building L3

Figure 45: L3 barely occupied

Ronwood Carpark Building

Accordingly, Ronwood Carpark Building will be the perfect fit for this assignment project to give back what it failed to deliver to the community.

Figure 46: Ronwood carpark building

[127] Bernard Orsman, "$14m empty carpark-that you paid for".

[128] Bernard Orsman, "$14m empty carpark-that you paid for".

It is an ideal location since it's close to tertiary education providers: Auckland University (AU), Auckland University of Technology (AUT) and Manukau Institute of Technology (MIT)); public transport hub (train & bus station); churches; public services (Ministry of Justice, police, fire brigades); shopping mall; Rainbow's End; and Hayman Park. As well, it may reduce car usage by eliminating 680 parking spaces, which could contribute to lowering carbon emissions. Undoubtedly, there is a huge opportunity and potential in this location.

Its location next to Hayman Park plays an important role in the overall design decision-making. The green open space influenced the design to connect the public to the programme, and the open spaces on the north, west and south make it easier to work with the design development. However, the proposed building is close to other buildings on the eastern side, which may potentially slow the design progression.

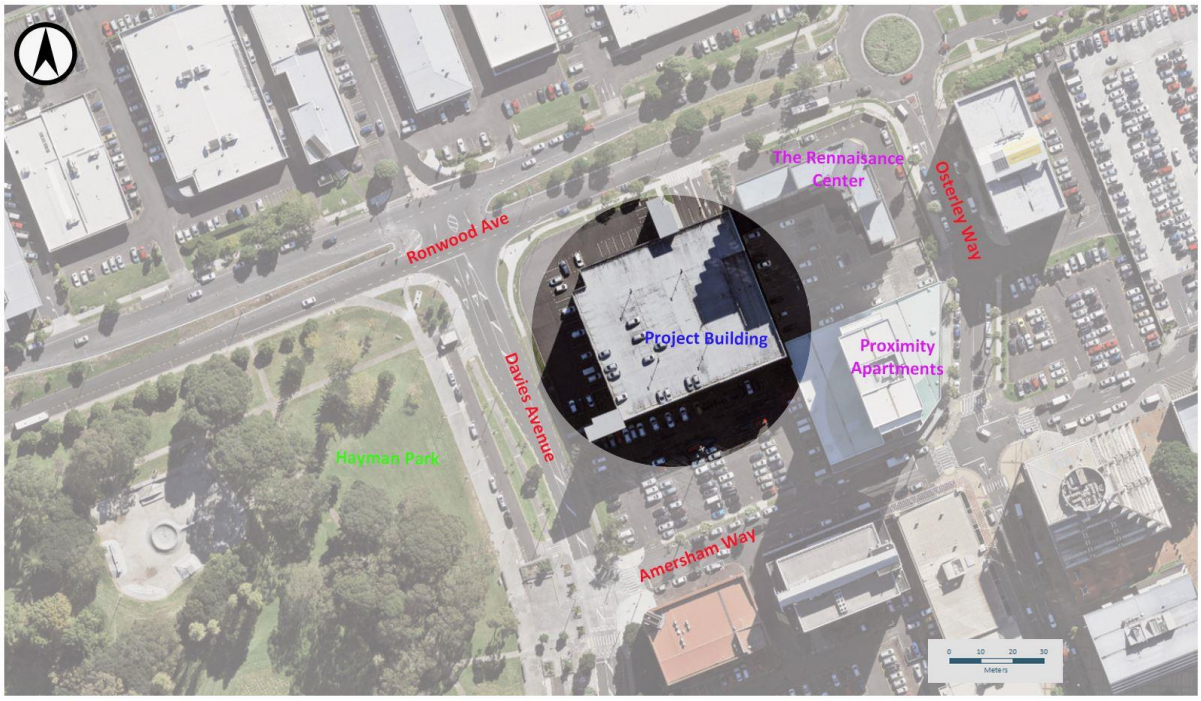


Figure 47: Surroundings of the project building

Design

The information obtained from the conversation with Letele helped to clarify the design development. It needs to be a safe establishment where those who seek health improvement fit in physically and socially, have considerable open space for gym equipment and bootcamp activities that allows for better movement for overweight people, and provide an open space with fresh air that is recycled frequently and naturally. Moreover, Letele highlighted that it is important to have a

walk-in health clinic without appointments within the premises for programme attendees, to save time and ensure they get immediate medical check results. Short courses will also be incorporated into the programme for upskilling purposes, hence more spaces need to be assigned in the new building design layout. These include incorporating a public kitchen station where BBM attendees can learn to cook and follow better diets. Furthermore, Letele wanted to have a kids' space, preferably a childcare unit where children can watch their parents or elders improve and transform their health. This should encourage children to do same and live a healthy life. Also, there need to be enough food bank spaces for storage and distribution activities. Lastly, private spaces are required for staff and for meetings with potential sponsors.

Iterative Design Process

In the early stage of designing the project, the programme planned to utilise only the western half of the building, from level 1 to level 3, while the rest of the building spaces remain as parking lots.

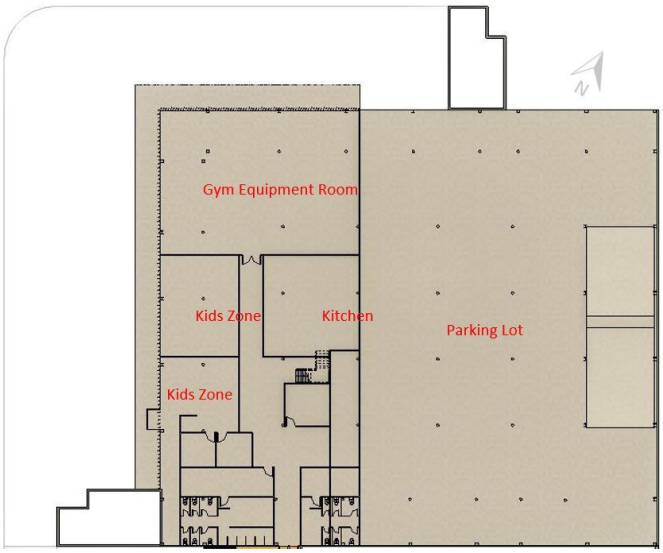


Figure 48: Level 2 (first proposed layout)

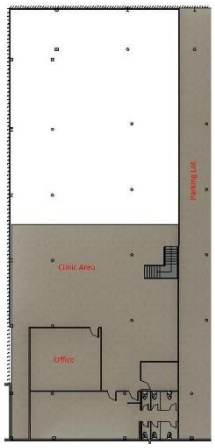


Figure 49: Level 3

As the design progressed, a hub for C&D waste was incorporated into the project. This hub was originally conceptualised to be located on the southern side of Ronwood carpark building on the ground level. This is a wide-open area that can be further developed to encourage foot traffic, creating a vibrant and lively atmosphere. However, after considerable time spent on design improvements, it was decided that the whole building will be utilised to house the BBM programmes as well as the hub. The rationale for this decision is that it will open up more potential for developing the project.

Figure 50: Plan concept with the C&D Hub located on the south side of the project building

In addition, northern, western and southern open spaces around the building will be renewed by introducing green landscaping to imitate the Hayman Park, creating a transition connection between the two sides of Davies Avenue.

Moreover, space is needed for the hub for C&D waste, where courses to upskill in woodwork will take place, and where C&D wooden waste will be sorted and displayed. The hub takes up about half of the eastern side of the building.

Structure

The rectanguloid carpark building, with a 2743-square-metre footprint and 55.635 metres x 49.300 metres x 26.900 metres in height, is constructed using assorted sizes of I-beam and I-column (some encased with concrete) steel structures held together by Comflor concrete floor slabs at each level. Each level is 2.7 metres in height from floor to floor with balustrade encasement of perforated steel panels at all elevations, and there are two standalone access cores on the southwest and northeast corners of the building.

Figure 52: Comflor and steel structure

Figure 51: Steel mesh balustrade

Figure 53: Steel structure joins

Re-purpose

The re-purposing of the building began by assessing what and how current materials can be re-used in the re-design of the whole car parking building. Since the new project building has to accommodate users of different sizes and cater to a huge volume of space for the wood C&D waste hub activities and storage processes, the alteration in floor height is needed. Sections of floors at certain levels will be cut out, removed and re-used as staircases. Steel structures that will be removed will be re-used as structural elements to erect two towers, one at the northwest corner of the building and the other located in Hayman Park, connected by a high walking suspension bridge. One of these steel structures will be used as hanging tracks for the heavy-duty over girder overhead crane that will be installed for the hub. The building will be divided into two by a vertical wall running from ground level to level 6 parallel to Davies Ave, and the rest of the building materials will be sourced from demolition yards and demolition and construction sites within a 20-kilometre radius.

Integrating C&D Waste

Material such as rubble from the visited demolition site will be used to fill up the staircase landscape area before topping it up with good soil for planting. Laminated long-span structural timber from Unitec building 202 will be utilised at level 8 for structural elements. The louvres on the northern and western elevations, balustrades, outdoor and indoor seats, furniture, planter boxes, and the rest of the finished interior linings will be made from C&D waste timber and wooden boards. In addition, all the interior and exterior fittings, joinery and doors, plumbing and bathroom supplies will be sourced from the Ward Demolition yard. Finally, the steel perforated sheets will be re-cut, assembled and used as ceilings or walls.

Conclusion

The idea of eliminating waste from the face of the earth is impossible, because where there are people, there will be waste. What is possible, though, is to convert waste to become valuable materials. As such, when something is valuable, people are more inclined to care for it. Needless to say, this architectural project research is only a tiny part of the bigger fight to achieve Auckland's Zero Waste goal by 2040.

The proposed project set out to address the C&D waste stigma that has been lingering for a long time, with its negative effects on the environment. This helped formulate the research question: 'How can architecture demonstrate the use of waste from C&D sites to help achieve Auckland Council's zero waste vision by 2040?' Generally, humans tend to react positively to a problem when

they fully understand the risks and implications. Thus, the project also aimed to raise awareness of the C&D waste problem within communities so that they are well informed, and to establish that C&D waste is as valuable as new building materials.

Firstly, the project prioritised utilising C&D waste salvaged within the Auckland area, and re-using materials taken out of the carpark building itself. In this manner, the whole building stands as a living witness, showcasing to the occupants that C&D waste is valuable as a building material and capable of delivering architectural satisfaction.

From a social perspective, the proposed building seeks to implement solutions to address the obesity issue in South Auckland by erecting a community-based centre that also 'raises awareness' around C&D waste. With this in mind, it will not only attract those who are seeking overall health improvement but will also encourage and inform the general public, families, professionals and entrepreneurs including designers about the C&D waste problem.

In keeping with this, the inclusion of a C&D waste hub that deals only with wooden materials salvaged across Auckland and offers carpentry and wooden craftsmanship courses is another method of informing and educating the community. The hub is also a source of C&D wooden waste processed to a saleable condition, together with furniture made on the courses.

Finally, the project itself is an opportunity to display the process of re-purposing a 'dead' whole carpark building into becoming a 'living' and meaningful piece of art that the locals can be proud of – a project that addresses the C&D waste problem and social issues, enhancing the connection between people and the environment, but above all creating a stepping stone towards achieving Auckland's Zero Waste Goal by 2040.

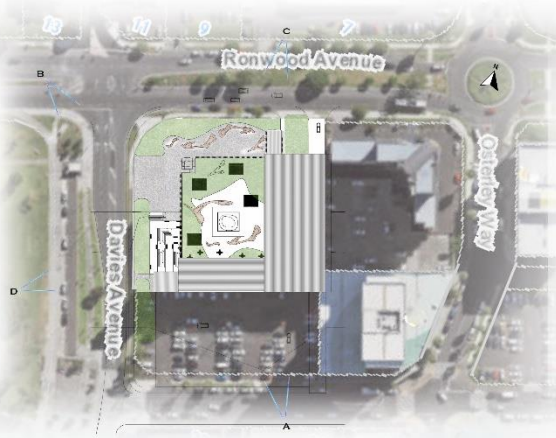
Final Design

VIEW A

VIEW B

VIEW C

BIRD VIEW



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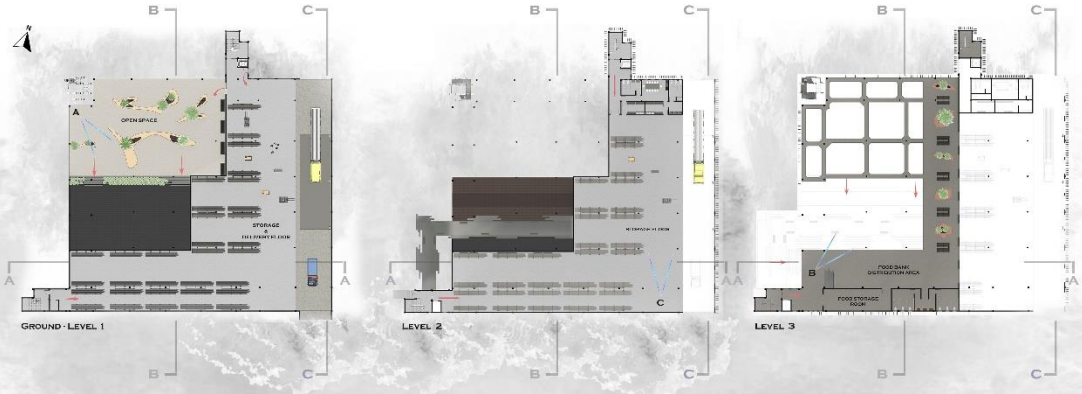

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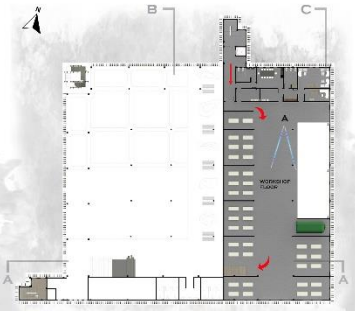

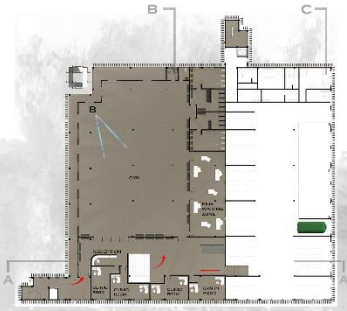

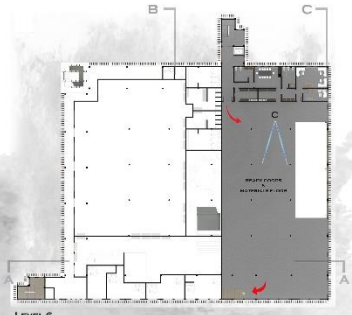

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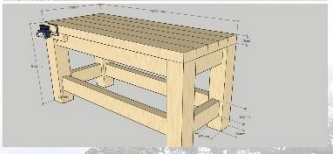

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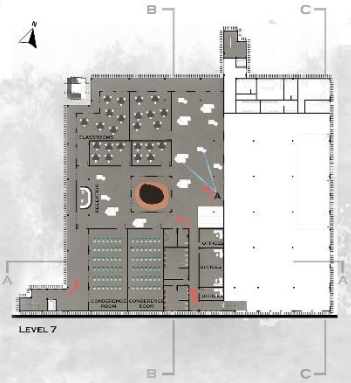

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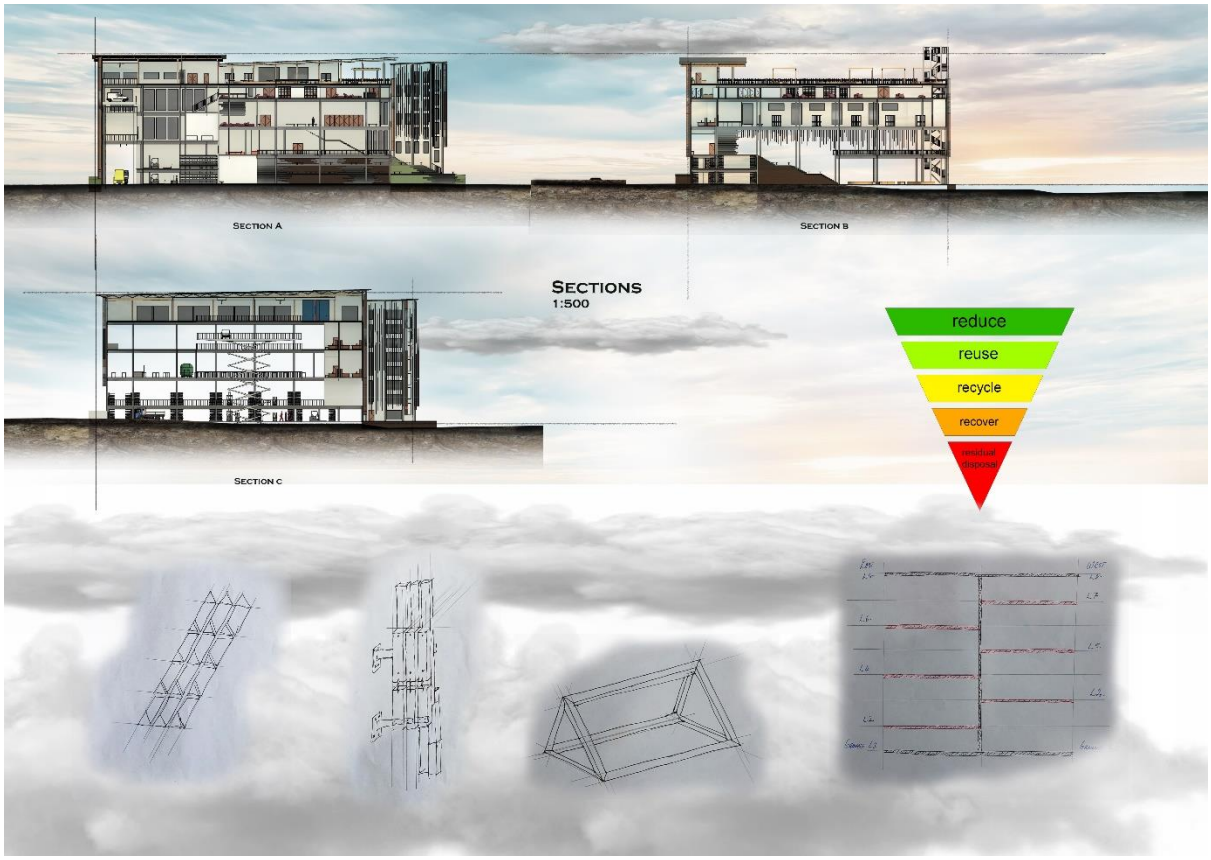
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SECTION C

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