University of Southern Queensland
Faculty of Health, Engineering and Sciences

Design of emergency housing from construction and demolition (C&D) waste materials

A dissertation by

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Abstract

Emergency housing is important in providing people in need with a basic standard of living. It needs to be readily available, easy to put in place and cost effective so that units can be provided as needed. For these reasons, the design of emergency housing is reduced down to the bare necessities to provide people with stable housing in the interim while they evaluate their future.

In this study, the aim was to develop an emergency housing model utilising environmentally friendly construction and demolition (C&D) waste materials. The design process involved sourcing C&D waste materials from a local waste management facility and determining what materials were sustainable and suitable for construction. Incorporating these materials, a holistic design was generated using a rainwater tank as the base structure. Investigations into the costs and logistics of the model found that it is realistic and effective to substitute C&D waste materials for industry standard materials to satisfy emergency housing requirements.

The proposed model was intended to be adaptable to suit the universal needs of the population. One of the ways this was effectively achieved was with a modularised design. In essence, the emergency housing model developed in this study is an effective example of how C&D waste materials can be implemented in emergency housing models.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Date

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List of Abbreviations

Abbreviation	Definition
BCA	Building Code of Australia
C&D	Construction and demolition
GTWMF	Greater Toowoomba Waste Management Facility
QDC	Queensland Development Code
RTEHM	Rainwater tank emergency housing model
TRC	Toowoomba Regional Council

Chapter 1 – Introduction

1.1 Why do we need emergency housing?

For most people, it is an afterthought as to whether they have a dry place to stay, a warm bed to sleep in or even just somewhere to call home. What if one day you had all of those things but then the next day you didn't? All of a sudden your entire livelihood is compromised and those same afterthoughts are now at the forefront of your mind and you don't know where you are going to go or what you are going to do. This is something that can happen to anyone at anytime and for many Australians it is an unfortunate reality. This is the reason why we need emergency housing.

Emergency housing is a crucial necessity in society as it provides shelter and a livelihood for individuals, families and even communities in times of need. It offers people an outlet and a chance to get back on their feet without having to worry about their day to day livelihood. Emergency housing can be useful for people whose lives are disrupted from any number of causes such as natural disasters, housing crisis, homelessness or any other perceivable reason that prevents people from staying at their home.

One of the most prevalent natural disasters in Australia is floods. The most devastating consequence of floods is that it can affect so many people all at once. One of the more recent incidents of flooding can be seen in the Northern Rivers floods in early 2022, where the most afflicted city of Lismore suffered the "biggest flood in modern Australian history." The floodwaters reached 14.4 metres and this left nearly 10,000 people homeless across the Northern Rivers region (Gilmore, 2022). Heritage towns and cities in regional areas such as Murwillumbah and Lismore are located along rivers as the only way for early settlers to viably transport their materials and resources inland was via these river systems. As a result, communities were built in close proximity to the rivers in flood prone areas. Over time, these established communities expanded and grew into the towns and cities of today which only exacerbates the flooding issue. This is a problem that doesn't have a definitive solution which unfortunately means residents of these towns and cities are always at the mercy of heavy rainfall events.

Figure 1 - Widespread damage of the Lismore floods in 2022

Source: (Brogden, 2022)

Another natural disaster that is prevalent in Australia is bushfires. Similar to floods, bushfires have the ability to wipe out communities and pose a large threat to the livelihood of those in them. The best example of this is the Black Saturday Victorian bushfires in early 2009. Heralded as one of the worst bushfire events in modern Australian history, in total over 450,000 hectares of land was burned and 3,500 buildings including 2,000 houses were destroyed. At the time, Deputy Prime Minister Julia Gillard recognised the bushfires as "tragedy beyond belief, beyond precedent and beyond words ... one of the darkest days in Australia's peacetime history" (National Museum Australia, 2023). In more recent times, the Black Summer Victorian bushfires of late 2019 and early 2020 are another example of the devastation bushfires can bring. In total, over 1.5 million hectares of land was burned and 300 houses were destroyed, resulting in approximately $18.6 million in insurance costs (Australian Government, n.d.).

Figure 2 – Aftermath of Black Saturday bushfires in Marysville

Source: (Morris, 2015)

As can be seen by both floods and bushfires, the nature of the natural disaster can vary drastically, from torrential rain to scorching temperatures yet the damage is always critical. Climate change has been linked to natural disasters more and more in recent history as a major contributor to their increased frequency. The Australian Institute for Disaster Resilience says that “average temperatures across Australasia have increased by about 1^{o}C since 1900 due to human-caused greenhouse gas emissions” (Australian Government, n.d.). This increase in temperature has resulted in a higher risk for bushfires, where climate scientists estimate that the extreme fire conditions experienced in the Black Summer bushfires were “at least 30% more likely due to climate change” (Walker, 2022). On the other end of the spectrum, the intensity of short duration, high volume rainfall events has increased by 10% in some regions of Australia (Walker, 2022). As a result, there are more instances of flash flooding as well as major flooding in prolonged rainfall events. An economic study commissioned by the Australian Business Roundtable for Disaster Resilience and Safer Communities (ABR) in 2021 showed that natural disasters currently cost Australia $39 billion annually. With the exponentially increasing impacts of climate change, this number is expected to jump up to $73 billion a year by 2060 (Kurmelovs, 2021). Hence, climate change is a major contributing factor in the increasing frequency of natural disasters which in turn impacts the livelihood of those affected.

Homelessness is another issue that can be aided by the implementation of emergency housing. According to the Australian Bureau of Statistics, the most recent census in 2021 discovered that approximately 123,000 people in Australia are homeless and two in five of those people were living in 'severely' crowded dwellings (Australian Bureau of Statistics, 2023).

Lastly, the global pandemic, COVID-19, is another example of where emergency housing could have been implemented. During the peak of the pandemic in 2020, countries all over the world introduced travel bans and strict policies to prevent the spread of the disease. Australia's response to the rapid threat of the disease was to impose mandatory 14 day hotel quarantines for international travellers returning home. This was due in part to a lack of exisiting government run facilities and having nowhere to house waves of incoming travellers who were potentially infectious. This put a lot of burden on the staff and facilities that were responsible for having to cater for these travellers under strict circumstances (Williams et al., 2022). Emergency housing could have been an alternate solution to this problem and allowed for people to isolate in a self contained unit at a designated location away from suburbia.

Emergency housing can also be provided as temporary housing for people who are affected by domestic violence as well as low income earners who have been displaced from their homes due to the current housing crisis in Australia (Dufty-Jones, 2017).

1.2 Outline of the study

The purpose of this study is to come up with an emergency housing model that is able to be built from C&D waste materials. In an ideal world, 100% of the model would consist of unprocessed C&D waste materials but this is not realistic due to the varying quality and availability of said materials. Hence, the more appropriate aim of this study is to design an emergency housing model that incorporates as many C&D waste materials with as little processing as possible to keep costs down.

1.3 Reusing waste materials

There are two different approaches to the handling of resources throughout their lifecycle – linear and circular. A linear economy is a take-make-dispose chain where natural resources are extracted out of the environment and used to make products which eventually end up being discarded once they are no longer of use. In this economy, natural resources are being underutilised due to their one-time use limitations and as a result their value is being trapped as waste. On the other hand, a circular economy aims to prevent waste by keeping the resources in circulation for longer by recycling and repurposing them. The CSIRO recognises that the fundamental principles of a circular economy are as follows:

1. "Eliminate waste and pollution
2. Circulate products and materials (at their highest value)
3. Regenerate nature"

(CSIRO, n.d.)

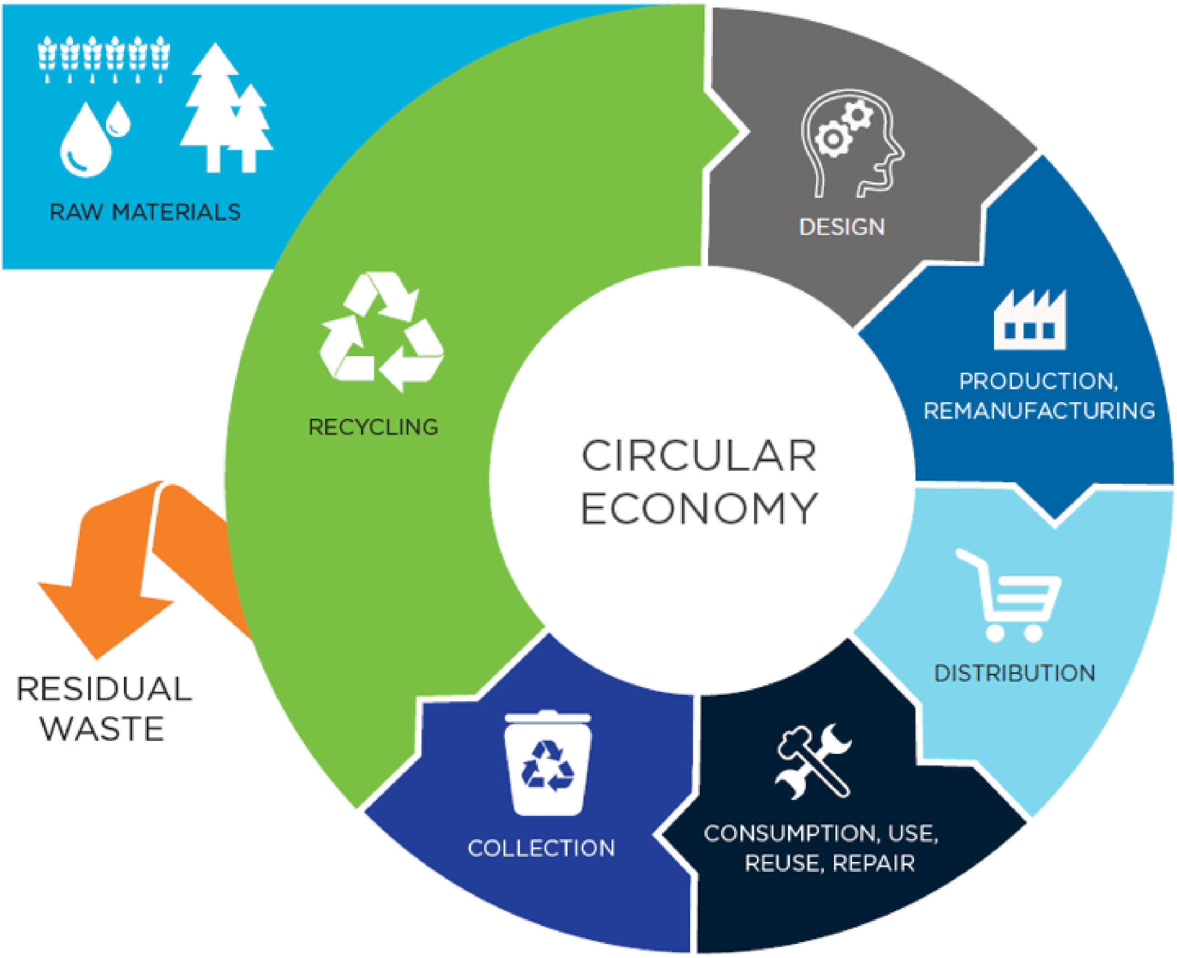

Figure 3 – Key phases of a circular economy

Source: (CSIRO, n.d.)

For the most part, society is stuck in a linear economy and is in need of a transition to a more circular economy. Not only is this necessary because it is more efficient and resourceful, but it will also help to tackle global issues such as climate change and biodiversity loss which are fuelled by the wasteful behaviours of a linear economy.

In the National Waste Report for 2020-21, it was found that Australia generated 75.8 megatonnes (Mt) of total waste. The distribution of this waste was as follows:

- 14 Mt of household waste;
- 32.8 Mt of commercial and industrial waste;
- 29 Mt of C&D waste.

(CSIRO, n.d.)

It was also discovered that Australia's recovery rate was 63% and the recycling rate was 60%. It was also of particular interest that waste generation had increased by roughly 20% over the last 15 years with the biggest increase coming from C&D waste which rose by 73% (Ridley, 2023).

Currently, Australia's economy is only about 3.5% circular which is significantly less than the global average of 8.6%. This is due to communities and industries being disconnected to waste policies as well as a lack of technological innovations. Through research and national initiatives, the CSIRO is aiming to create a $30 billion economic opportunity and raise the circular economy to 30% by 2030. This will involve discovering new ways to improve the current recycling climate, such as:

- "Build and integrate national inventories for data, material volumes, values, places and flows;
- Develop and implement new technologies for waste treatment, resource recovery and safe reuse of secondary materials at scale;
- Enable decision-makers to make well-designed and evidence-based policies; and,
- Identify, develop, and support new circular markets and business models."

(CSIRO, n.d.)

Although there are already measures in place to turn the corner as a circular economy, there is still a long way to go. The ability to reuse and repurpose waste materials plays a critical role in reducing the environmental burden of waste facilities. It prevents new materials from having to be created which in turn reduces not only production costs but ultimately the amount of waste materials that end up in landfill. This project aims to apply the principles of a circular economy. This will be achieved by renewing the lost value of waste materials and repurposing them as circular products to extend their lifecycle.

1.4 Problem statement

The crux of the issue with C&D waste materials is that they are deemed to have no further value past their initial use and hence get discarded to landfill where they take up large quantities of space. This is a problem as it is not sustainable to keep piling up C&D waste materials. This behaviour will lead to landfill sites reaching capacity at a quicker rate and forcing expansion into more land (Pickin, 2009). Currently, there are measures that are used to lighten this burden on the environment. For example, concrete is crushed up into aggregate and used as a base course for road construction and timber is shredded down and refined into mulch so it can be used for gardening purposes. Landfills have significant environmental and social impacts such as producing toxic gasses, leaching ammonia into the soil and water table as well as increased health risks for nearby residents (Vasarhelyi, 2021). The way this study aims to address the problem at hand is to redeem the lost value of these C&D waste materials and discover a way to use them that makes them viable emergency housing components.

1.5 Aims and objectives

The following aims and objectives are proposed for this study.

Aims:

- Use environmentally friendly C&D materials i.e. no asbestos, treated pine etc.;
- Build as much of the emergency housing model from C&D waste materials as possible;
- Create a holistic design that can be produced in multiple locations and in multiple configurations;
- Design the emergency housing model so that it is easy to assemble with a small team of people within a short timeframe.

Objectives:

- Design an emergency housing model for under $30,000;
- Emergency housing modules to be less than 1000 kg.

Chapter 2 – Literature Review

2.1 Introduction

The first stage of this study is to do independent literature reviews of both emergency houses and C&D waste materials. By gaining an understanding in these fields, we will hopefully be able establish a common link that will allow us to come up with an effective design that takes inspiration from literature.

2.2 Existing temporary housing models

The best place to start for this study is to look into existing temporary housing models that are already on the market. This search is purely for inspiration to see what is out there and what our potential design will need to compete against.

2.2.1 Prefabricated modular tiny homes

Perhaps the most common form of emergency housing is prefabricated modular homes. These types of temporary housing are so effective that some people voluntarily choose to make them their permanent residence as they are a much more affordable option compared to building a house. The benefit of these houses is that they are easily transportable due to their compact design which means that they are easy to load on and off trailers with minimal effort. Likewise, they are also simple to install, typically within a few hours. The only foundational requirements for their installation are a concrete slab, concrete piers or wooden beams to support the structures as well as vehicle access to the site (Boxabl, n.d.).

Good examples of these prefabricated modular homes are those created by a company called Boxabl. The company was founded in 2017 to supply accessory dwelling units. Their original tiny home model, Casita, offers a 361 square feet (33.5 square metres) space that can be designed whichever way you want. They have separate modules for bedrooms, living areas and kitchens and can even offer double story living. They can also be joined together to truly create a homely feeling with separate rooms. They recently received lots of attention by promoting their association with renowned tech billionaire Elon Musk who purchased the

Casita and uses it as a guest house near his current residence in Texas. He even claims to have hosted a birthday party at it. The Casita costs $49,500 USD (approximately $80,000 AUD) and comes fully furnished with all interior fittings and amenities. (Boxabl, n.d.)

Figure 4 – Single and double story Casita models from Boxabl

Source: (Built Offsite, n.d.)

The individual modules are constructed in a factory where they can be mass produced using computer controlled equipment. The materials are pre-cut and assembled over six specialised stations by home building specialists. Boxabl claims that this design process can reduce the time it takes to construct a two bedroom home to near completion from six months to six hours (Boxabl, 2021).

The materials used to build the modules are steel, concrete and EPS foam. The walls are of a composite build with a single support beam to provide ample space for wiring and other utilities (Boxabl, n.d.).

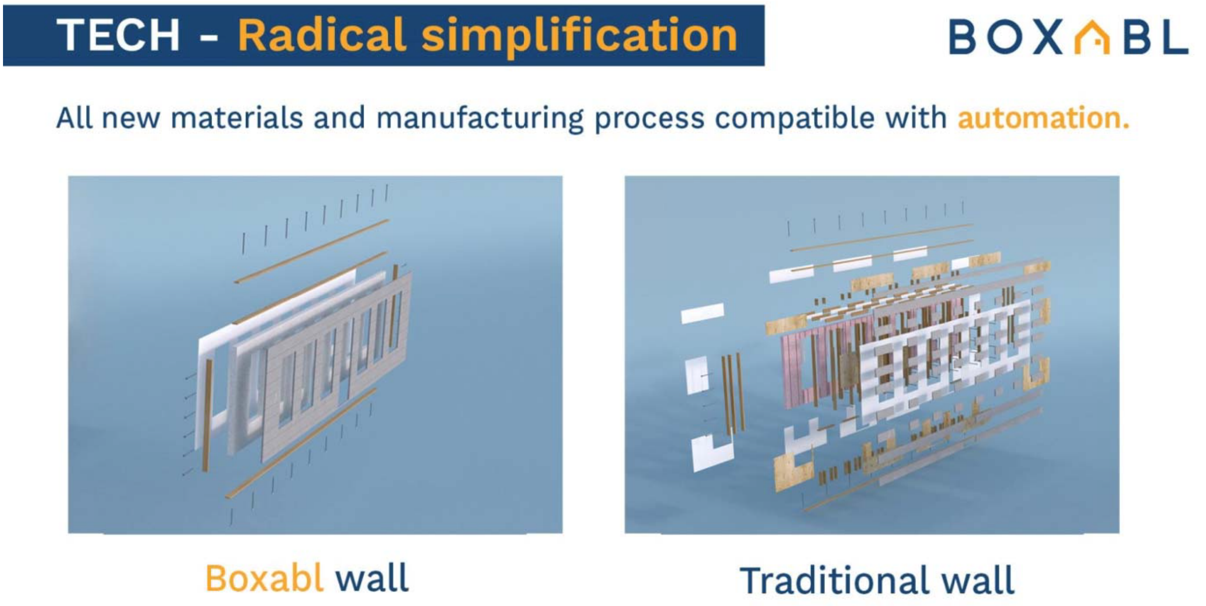

Figure 5 – Comparison of traditional walls and composite walls used in Boxabl homes
Source: (Boxabl, n.d.)

The end product results in a prefabricated module that is 42 feet (12.8 metres) long by 18 feet 9 inches (5.7 metres) wide once assembled. However, when it needs to be transported it can fold down to a width of 8 feet 6 inches (2.6 metres). At this size, they satisfy transport regulations and are not considered oversized loads. Depending on the module, the maximum weight of a single unit can be up to 12,000 pounds (5.5 tonnes) and can safely be transported using a regular service vehicle or tray truck (Boxabl, 2021).

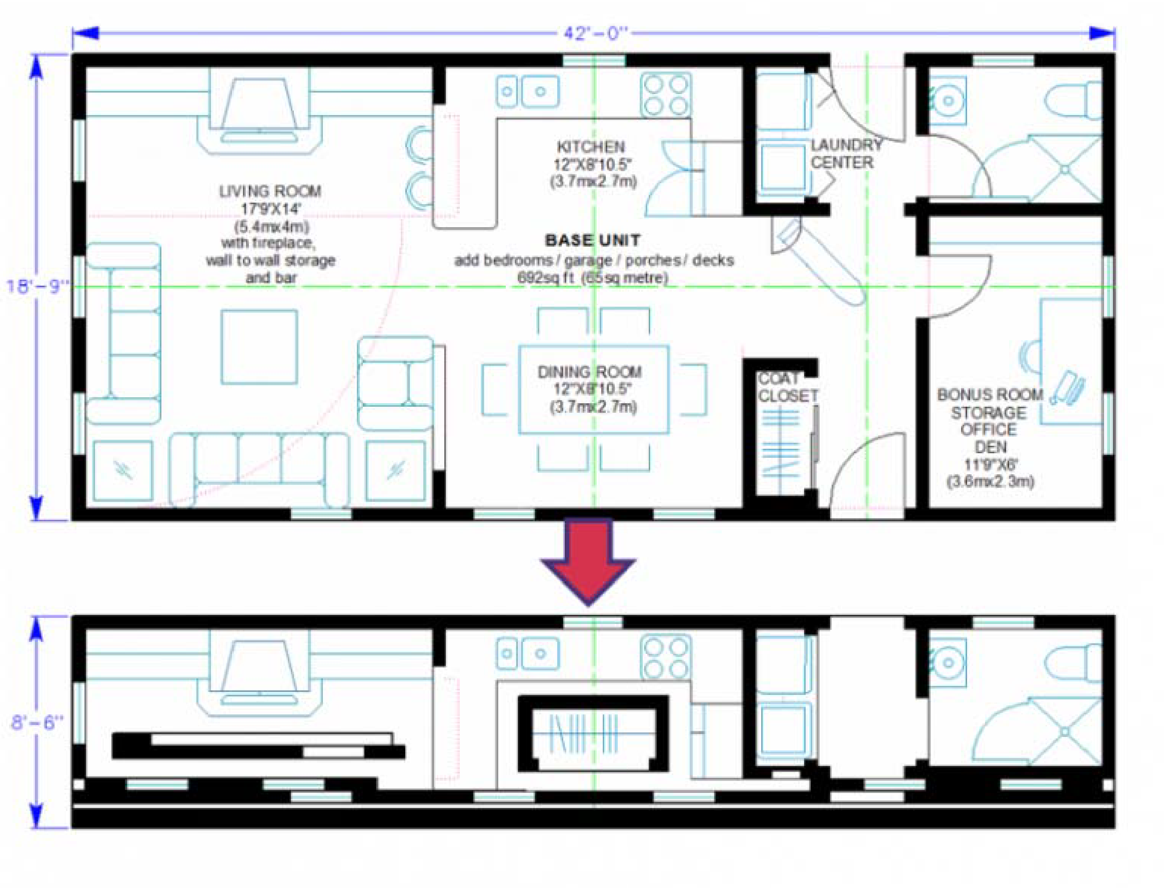

Figure 6 – Floor plans of Boxabl homes in their open and compact forms

Source: (Boxabl, n.d.)

Figure 7 – Transportation of Boxabl homes

Source: (Boxabl, 2021)

The modules have state modular approval in every state in America. This means that the modules can be assembled without the need for engineering certification which in turn saves on costs. In accordance with ANSI 119.5, the modules are certified as a "park model RV" which lessens the amount of restrictions and incurred costs (Boxabl, n.d.). Granted, these building codes are only applicable in the United States, but Boxabl does offer their product to international customers as well. The modules would only require minor amendments, if any, to satisfy the differing regulations and standards of other countries.

The ability to easily transport and set up these prefabricated modular tiny homes is a major factor in their suitability for emergency housing. Combine this with the ability to mass produce them in factories and it's easy to see why they are the gold standard for temporary housing. The only downfall of a prefabricated home is that everything is set as is and there is no way to change the layout to another configuration. This may make it more difficult to meet the specific needs of all individuals or families.

In particular, the key elements of modular capacity and transportability are the main benefits of this type of temporary housing and will be closely monitored throughout this study.

2.2.2 Mobile tiny homes

The majority of people in society have a designated home that they live in and then some form of transport that they use to get around. However, there are approximately 123,000 people in Australia who are homeless (Australian Bureau of Statistics, 2023) and may very well have no other choice but to live out of their vehicle, if they even have one. In a separate category altogether, there are some people who voluntarily choose to operate out of their vehicles whether it be due to travelling or just because it's a cheap way to live. Vehicles such as vans and buses are often renovated and converted to provide a liveable environment. This can be done at a low end scale or to a high degree with an appropriate budget. Regardless, the concept of having a mobile house is something that a lot of people value. Mobile living is the main focus for companies such as VanHomes and Aussie Tiny Houses who produce ready to go mobile tiny homes.

VanHomes was founded in 2008 and specialises in building demountable homes onto a trailer chassis. This means that they are easily relocatable simply by towing them away. Essentially, they serve the same purpose as a traditional caravan albeit in a more permanent setting. Since they are a registrable caravan, they can be used as a tertiary dwelling without the need for council or building approvals (VanHomes, n.d.).

Figure 8 – Portable VanHomes trailer home
Source: (VanHomes, n.d.)

The homes come in a variety of sizes, ranging from 17-60 square meters. For reference, the average size of an apartment in the centre of Sydney is 42 square metres (VanHomes, n.d.). The pricing varies depending on the type of suit as well as the size of it. For reference, the smallest single expanding suite which is 34 square metres is priced at $88,320 but the largest double expanding suite which is 59 square metres is priced at $130,710 (VanHomes, n.d.).

Aussie Tiny Houses is another company that specialises in building tiny houses on wheels (THOW). They were founded in 2017 and have sold over 250 in that time. They have a vast selection of THOW that are fully furnished and ready to go. Some of their bigger options can sleep up to 6 people due to having lofts which grant an extra queen size bed. The cost of a complete turn-key Aussie Tiny House starts from $96,900 (Aussie Tiny Houses, n.d.).

Similar to VanHomes, they are situated on a trailer chassis and can be towed anywhere behind a car.

Figure 9 – Teewah 7.2 model Aussie Tiny House

Source: (Aussie Tiny Houses, n.d.)

As a means for quick and accessible housing in an emergency setting, these homes would provide comfortable living and be a good alternative for people transitioning back into normal life.

2.2.3 Pods

The most traditional form of emergency housing is a small unit that is fabricated in a construction yard and transported to site. These types of houses are broadly called pods and they include caravans, modules and shipping containers. The benefit of building them offsite is that they are able to be mass produced in a construction environment and sent anywhere they are needed. This is especially relevant for when a lot of emergency houses are needed at the same time potentially due to a natural disaster. The best example of this can be seen in the

Northern Rivers floods in 2022 when thousands of people lost their homes and were in need of emergency housing.

The main response to the housing crisis caused by the Northern Rivers floods was to build villages with pods to house the people who were displaced from their homes. Some of the housing units provided were Minderoo pods and Hutchinson modules. The Minderoo pods are small shipping containers that come equipped with a water tank, generator, toilet, shower, bunk beds and kitchen. Each recovery pod costs approximately $30,000 (Minderoo Foundation, n.d.).

Figure 10 – Minderoo pod

Source: (Minderoo Foundation, 2020)

A purpose built village comprising of these Minderoo pods was completed in March 2023 in Wollongbar on the local sports field. In total, it hosts 107 dwellings and houses up to 336 people who are still unable to return to their homes due to the Northern Rivers floods. They range in size from studio to 4 bedrooms and are available to residents for up to 2 years (NSW Government, 2023).

Figure 11 – Wollongbar village
Source: (NSW Government, 2023)

The Hutchinson modules are built offsite at the company's Toowoomba Modular Yard and then distributed to the Northern Rivers. The flexible design of the modules revolves around installing a base studio, which has all of the required essentials, and then attaching bed modules as needed to accommodate any family size. They arrive as a 'flat pack' and are constructed onsite by Hutchies staff (Hutchinson Builders, n.d.).

Six new residential villages are to be constructed by using over 730 modules in a 28 week timeframe. One of the premier villages underway is Wardell and Hutchies are taking all of the measures to make it as close to home for the residents. The village will include parks, sporting fields and BBQ areas and even a school facility (Hutchinson Builders, n.d.).

Figure 12 – Wardell village under construction
Source: (Hutchinson Builders, n.d.)

The modules are able to be produced at a rate of 10 individual modules per day and the entire construction phase from conception to completion is expected to only take 7 months. The project team leader, Sean Lees, spoke of the importance of emergency housing by commenting that “you’re literally taking someone out of a tent and putting them into a safe home that’s going to put a roof over their children’s head” (Hutchinson Builders, n.d.). This statement encapsulates the pivotal role emergency housing plays in providing an increased standard of living for those who are already doing it tough.

2.2.4 Comparison of existing temporary housing models

With a selection of temporary housing models, it is important to compare them in a decision matrix that identifies the key criteria that would make a temporary housing model viable as an emergency housing model. The rating system is a scale from 1 to 5 where a higher score indicates more effectiveness and better performance.

Table 1 – Decision matrix for evaluating existing temporary housing models

Temporary housing model	Prefabricated modular tiny homes (Boxabl)	Mobile tiny homes (VanHomes / Aussie Tiny Houses)	Pods (Minderoo pods / Hutchinson modules)
Cost	3	2	5
Size	4	4	2
Modularisation	5	2	1
Ease of assembly	3	3	4
Transportability	3	3	3
Sustainability	4	3	3
Total	**22**	**17**	**18**

Key:

1	Poor
2	Unsatisfactory
3	Satisfactory
4	Very satisfactory
5	Outstanding

From this decision matrix, it can be seen that the prefabricated modular tiny homes are the most effective forms of temporary housing. This is due mostly in part to the modularisation that the other housing models simply do not have. The ability to add more modules makes the design more dynamic and allows for more scope to suit a variety of users. Apart from the modularisation, the other housing models fared pretty evenly across the board as they all inherently have the same purpose. The only significant difference was the cost where the pods were by far the most cost effective housing model due to them being built from easily accessible materials and fitted out with the bare minimum requirements to satisfy building codes. For this project, the aim is to come up with an emergency housing design that is similar in build quality to the pods yet has the ability to be modular like the prefabricated tiny homes.

2.3 Construction and demolition (C&D) waste materials

C&D waste is a constant in today's society where construction and development occur in a loop. In 2018-2019, Australia generated over 27 million tonnes of C&D waste, however only 60% of this was recovered and reused with the rest going to landfill (Kabirifar, 2021). The construction industry spent approximately $2 billion on waste services which was the most of any sector as well as a 35% increase since 2016-17 (Australian Bureau of Statistics, 2020). With such a large amount of C&D waste being underutilised, it will require an innovative solution to find a new purpose for this landfill bound waste in order to achieve the goal of zero waste. Hence, this study aims to come up with a satisfactory design of emergency housing using these said C&D waste materials.

2.3.1 Management of C&D waste

In order to design an emergency housing model from C&D waste materials we need to have an understanding on their life cycle and how they are handled after their initial use. The first item to assess is determining what types of materials constitute as C&D waste materials as well as how they are managed.

The definition of C&D waste as detailed in the *National Waste Report 2010:*

> "... waste produced by demolition and building activities, including road and rail construction and maintenance and excavation of land associated with construction activities. The C&D waste stream usually covers only some of the generation, disposal and recycling of C&D wastes, as these materials can also be found in the Municipal Solid Waste (MSW) and Commercial and Industrial (C&I) streams, or as hazardous wastes."
> (Australian Government, 2011)

Construction waste is entirely dependent on the standard building practices at the time as well as the location of the site. For instance, most of the houses built in countries like Australia, Canada and the United States have wooden frames whereas stone and brick homes are more common in Europe and the United Kingdom. A US study determined that the construction waste materials for a typical timber framed house consisted of wood (42%), gypsum board (27%), plastics and others (15%), brick (6%), roofing (2%) and metals (2%) (Jeffrey, 2011). During construction, less valuable materials such as gypsum board and brick will be used wastefully due to being cut to size and breakage. On the other hand, more expensive resources such as roofing materials and metals are only used as needed and as a result there is less wastage.

Demolition waste differs from construction waste in that it comes from removing existing structures. This means that a variety of materials can be uncovered, even hazardous ones that are no longer used today such as asbestos. Due to whole structures being torn down, the amount of waste materials is substantially greater compared to construction waste, particularly with valuable resources that are used efficiently such as metals. It is said that approximately 60% of residential and 80% of non-residential demolition waste consists of wood, concrete, brick and masonry. Furthermore, it is estimated that there is approximately 9.8 kg of demolition waste per square metre removed (Jeffrey, 2011).

In general, C&D waste is lumped together in the same category due to both construction waste and demolition waste consisting of the same materials. For example, timber as construction waste could come in the form of off cuts that are still relatively untouched whereas timber as demolition waste could be split, painted, fastened together and almost always altered from its original state. To compound the issue, demolition projects produce approximately 20 to 30 times as much waste as construction projects (Jeffrey, 2011). Although demolition waste is less desirable than construction waste, it presents too much of a challenge to sort between the two types, hence it is standard practice to combine the two as C&D waste.

With an understanding on the types of C&D waste materials and where they come from, the next step in the process is to determine how they are managed once received at a waste facility. The following materials are of particular interest:

- Aggregates
- Asphalt shingles
- Wood

- Gypsum board
- Metals
- Glass
- Plastics
- Carpeting / ceiling tiles / insulation

2.3.2 C&D waste management regulations

Waste management is governed by a number of regulations that have been steadily implemented and expanded upon over the years. They aim to control the inflow and processing of waste as well as recycle and reuse materials that would otherwise go to landfill. Below is a list of the legislative framework that resides over waste management in Australia.

Table 2 – Legislative framework of waste management in Australia

State and territory	Act, regulation, policy, and specification
NSW	Protection of the Environment Operations Act 1997
	Waste Avoidance and Resource Recovery Act 2001
	Protection of the Environment Operations (Waste) Regulation 2014
	Extended Producer Responsibility
	State Environmental Planning Policy No 48 1995 - Major Putrescible Landfill Sites
	State Environmental Planning Policy (Major Projects) 2005
	NSW Government Sustainability Policy 2008
	Specification for Supply of Recycled Material for Pavements, Earthworks and Drainage 2010
	Road and Maritime Services Technical Guide-Management of road construction and maintenance wastes 2016
	Standards for managing construction waste in NSW
VIC	The Environment Protection Act 1970
	The Environment Protection (Resource Efficiency) Act 2002
	The Environment Protection (Amendment) Act 2006
	Sustainability Victoria Act 2005
	Environment Protection (Distribution of Landfill Levy) Regulations 2010
	Environment Protection (Industrial Waste Resource) Regulations 2009
	Industrial Waste Management Policy (Waste Acid Sulfate Soils) 1999
	Waste Management Policy (Siting, Design and Management of Landfills) 2004
	Waste Management Policy (Used Packaging Materials) 2010
	VicRoads Standard Specifications for Roadworks and Bridgeworks
	Waste Management Policy (Movement of Controlled Waste Between States and Territories)

	2002
QLD	Environmental Protection Act 1994
	Environmental Protection (Waste Management) Regulation 2000
	Environmental Protection Regulation 2008
	Waste Reduction and Recycling Act 2011
	Waste Reduction and Recycling Regulation 2011
	The Environmental Protection (Waste Management) Policy 2000
	Main Roads Specification MRS35 - Recycled Materials for Pavements
	Transport and Main Roads Specifications MRTS36 Recycled Glass Aggregate
	Transport and Main Roads Specifications MRTS102 Reclaimed Asphalt Pavement Material
	Recycling policy for buildings and civil infrastructure
SA	Environment Protection Act 1993
	Development Act 1993
	Zero Waste SA Act 2004
	Environment Protection (Waste to Resources) Policy 2010
	Standard for the production and use of Waste Derived Fill
	Recycled Fill Materials for Transport Infrastructure - Operational Instruction 21.6 Policy
	Specification: Part 215 Supply of Pavement Materials
WA	Environmental Protection Act 1986
	Waste Avoidance and Resource Recovery Act 2007
	Waste Avoidance and Resource Recovery Levy Act 2007
	Environmental Protection Regulations 1987
	Environmental Protection (Controlled Waste) Regulations 2004
	Waste Avoidance and Resource Recovery Levy Regulations 2008
	Waste Avoidance and Resource Levy Regulation Administration Policy 2009
	Extended Producer Responsibility Policy Statement
	Main Roads Western Australia Specification 501 – Pavements
TAS	Environmental Management and Pollution Control Act 1994
	Environmental Management and Pollution Control (Waste Management) Regulations 2020
	Environmental Management and Pollution Control (Controlled Waste Tracking) Regulations 2010.
	Litter Act 2007
ACT	Environment Protection Act 1997
	Environment Protection Regulation 2005
	Waste Minimization Act 2001
	Waste Management and Resource Recovery Regulation 2017
	Waste Management and Resource Recovery Act 2016
NT	Waste Management and Pollution Control Act 1998
	Waste Management and Pollution Control (Administration) Regulations 1998
	Environment Protection Act 2019
	Environment Protection Regulations 2020
	Northern Territory Environment Protection Authority Act 2012

Source: (Zhao et al., 2021)

2.3.3 National waste targets

The National Waste Policy Action Plan was implemented in 2019 to provide a guideline for restructuring waste policies and funding waste initiatives to improve waste recovery. In it, there are 7 targets with 80 underlying actions which involve collaboration between the community, industry and all levels of government. Below is a list of these targets and what they aim to achieve.

Table 3 – National Waste Policy Action Plan waste targets

Target	Aim	Progress
Target 1	*Ban the export of waste plastic, paper, glass and tyres, commencing in the second half of 2020.*	Export bans are underway for plastic, glass and tyres with restrictions due in July 2024 for paper and cardboard
Target 2	*Reduce total waste generated in Australia by 10% per person by 2030.*	3% increase since 2016-17.
Target 3	*80% average resource recovery rate from all waste streams following the waste hierarchy by 2030.*	2.2% increase since 2016-17.
Target 4	*Significantly increase the use of recycled content by governments and industry.*	15% increase since 2016-17.
Target 5	*Phase out problematic and unnecessary plastics by 2025.*	• The National Plastics Plan released in 2021. • Environment ministers have agreed to ban eight problematic and unnecessary single-use plastic products. • Lightweight single-use plastic bags are banned across the country. • The Australian Packaging Covenant

		Organisation (APCO) has released an Action Plan for Problematic and Unnecessary Single-Use Plastic Packaging and established the ANZPAC Plastic Pact.
Target 6 (omitted)	-	-
Target 7	*Halve the amount of organic waste sent to landfill by 2030.*	3% increase since 2016-17.
Target 8	*Make comprehensive, economy-wide, and timely data publicly available to support better consumer, investment, and policy decisions.*	The government has released numerous reports and databases since the commitment was made, including creating a national standard for waste resource recovery reporting.

Source: (Ridley, 2023)

2.4 Temporary housing guidelines

Every structure that has been built has been made to satisfy certain guidelines, standards or legislative codes. This can be anything from local council practices to nationwide Australian Standards. In relation to temporary housing, the level of detail is less than if you were to build a more prominent and permanent building but there is still some rules that need to be followed. The following guidelines are imposed for temporary housing.

2.4.1 Queensland Development Code MP 3.3 – Temporary Accommodation Buildings and Structures

Queensland has a number of building codes that must be adhered to when building any type of structure. The relevant development code for this study is MP 3.3 – Temporary Accommodation Buildings and Structures. This code is responsible for outlining the requirements of temporary accommodation and since emergency housing falls under the category of temporary accommodation, it applies.

Despite only being temporary housing, the list of requirements is still quite large and demands some level of thought and attention to be put in. A certain level of livelihood is to be maintained in temporary housing and the codes dictate this in turn. The inclusion of potable water, amenities and electrical outlets are only some of the main requirements of the code. For the full scope of the development code, see Appendix D – Queensland Development Code MP 3.3.

Chapter 3 – Methodology

3.1 Design process

In order to develop an emergency housing model a design process needs to be implemented so that the stages are nominated and all aspects are included. Figure 13 below shows the design process in a generalised form.

Figure 13 – Design process flow chart

The first stage, as already seen earlier in this project, is to conduct a literature review. By gaining an understanding of the different types of emergency housing and the roles they play, it gives us a feel for where the project is headed and the potential uses that our design could have. Secondly, it is also imperative that we investigate the lifecycle of C&D waste materials and identify ones that have the ability to be repurposed as housing materials. These are the main areas of focus during the literature review and from this a few ideas are to be generated for further exploration later in the design process.

The next stage in the design process is to get a real perspective on how the waste industry operates and this is achieved by visiting a waste management facility. The one in question is GTWMF due to its locality to the area and the central role it plays as the hub for waste in the Toowoomba region. The main purpose of this site visit is to gain an understanding on the treatment of waste and how it is processed for recycling or landfill. This will allow us to characterise the materials and determine which ones are sufficiently being reused or perhaps underutilised. A material void may become apparent and present an opportunity to create a closed loop by repurposing unused waste materials as emergency housing materials.

The next stage in the design process is to come up with an initial concept level design that uses the knowledge gained from the literature review along with the information gathered during the site visit. This concept level design will be responsible for developing the concept of an emergency housing model which means focusing more on nailing down the core ideas and materials as opposed to specific design details. These sketches will be done using an Autodesk product called AutoCAD as 2D sections to provide the base level of detail.

Following the development of an initial concept design, a cost analysis will need to be performed to introduce a ballpark number into consideration. This is an important step in the design process as it could make or break the project. If the cost analysis indicates that the production costs of constructing the concept design are too high, it would mean that the design needs to be amended or scrapped altogether. On the other hand, if the costs are acceptable then it means that the concept design is realistic and has plausible merit going forward.

Once the costs are finalised, the next stage in the design process is to assess the feasibility of the design. This means figuring out the logistics of sourcing the waste materials and assessing how sustainable their supply would be under constant construction demand. The assessment will also take into consideration factors such as transportability and how the emergency housing will be assembled, either in a construction yard or on site. Essentially, we need to ensure that all the logistics are mapped out and there are no perceivable obstacles that may otherwise cause the design to fail. Another important aspect of the feasibility assessment is to compare our design to existing models in the market. By doing so, we will be able to get a feel for how our design stacks up against the competition and gauge how viable and desirable it will be relative to similar products that serve the same purpose. Ideally, we may be able to identify a gap or niche in the field that can be filled by our design.

With all of the above stages taken care of, the next step is to flesh out the concept design by diving into detailed design. This will be completed in another Autodesk product called Revit as a one to one 3D representation of the emergency housing model. The final design will need to meet standard construction requirements and for this project the governing framework will be the QDC MP 3.3 – Temporary Accommodation Buildings and Structures. The aim of this stage is to grind out all of the details in the design whilst making sure that it meets the appropriate regulatory requirements. With the design finalised, it will also be prudent to do a revised cost analysis and prepare a schedule list of materials.

The final stage in the design process is to wrap up the project with a conclusion. This will involve holistically reviewing the entire design process now that all of the critical factors are known. In essence, this can be likened to running a fine-toothed comb through our prior work to ensure that all of the requirements are accounted for and details are accurate. Once this is completed, we will provide a recommendation of our design and highlight some of the ways that we believe it could best be implemented. If there are to be any shortcomings along the way or areas that we believe could be improved, they will also be noted in the conclusion.

3.2 Source of materials (GTWMF)

The aim of this project is to develop a concept design of emergency housing using C&D waste materials. For the Toowoomba region, GTWMF is the primary destination for the majority of these C&D waste materials. Hence, a site visit was necessary to get a better grasp on the C&D industry and discover what is available for re-use.

3.2.1 Site visit

The site visit took place in late February and the weather was clear so the site was able to be fully explored. The head of Principal Program Development, Norm Purcival, was the guide for the site visit. The facility is located approximately 12 km west of the Toowoomba CBD (refer to Figure 14) and is the hub for all surrounding waste centres. It opened in 2016 and cost $20 million to build. It is responsible for handling approximately 150,000 tonnes of waste per annum.

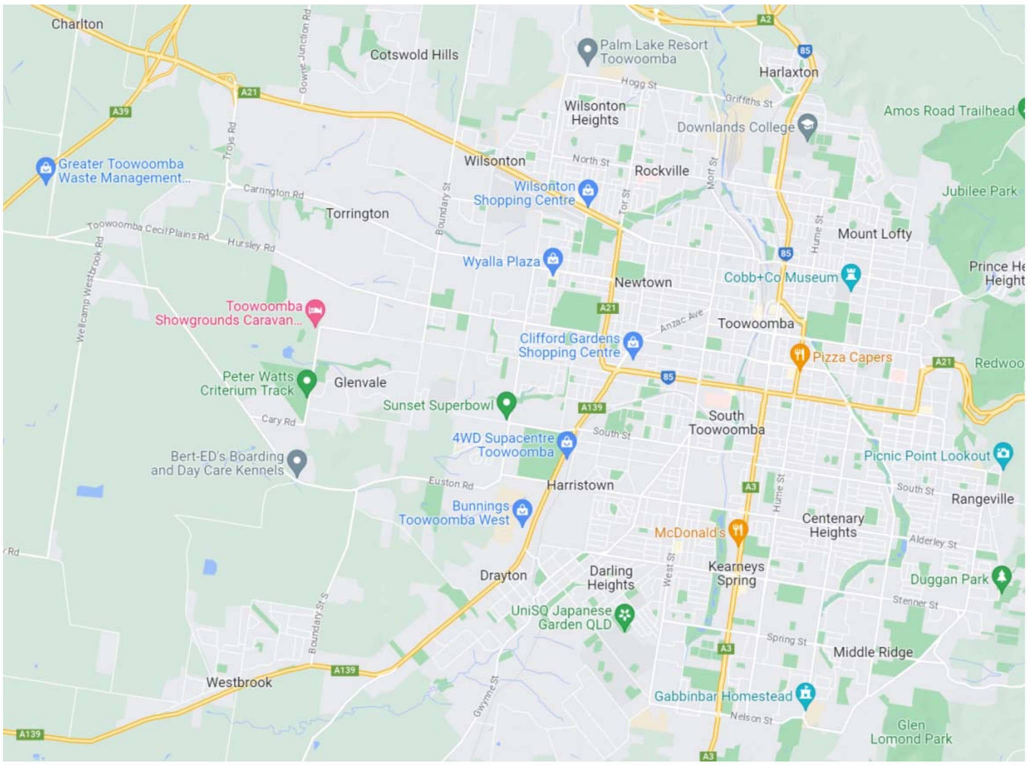

Figure 14 – Locality map of GTWMF

Source: (Google Maps, 2023)

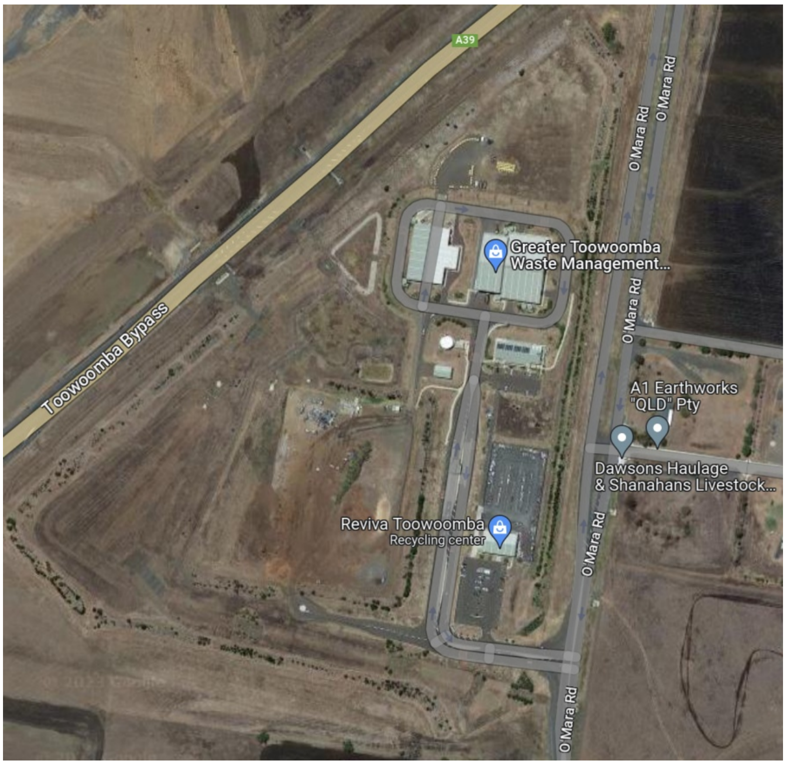

Figure 15 – Layout of GTWMF

Source: (Google Maps, 2023)

The first area of the site visited was Zone A. This area collected all green waste, scrap metal, concrete and inert waste.

Figure 16 – Bulk materials area (Zone A)

Source: (O'Connor, 2023)

Zone A is located in the south-western area of the facility. It is entirely outside and open to the elements. Cars are able to drive right up to the waste piles and unload their waste.

Figure 17 – Raw timber waste

Source: (O'Connor, 2023)

Figure 18 – Variety of raw timber waste

Source: (O'Connor, 2023)

The raw timber scrap piles that are shown in Figure 18 effectively demonstrate the sheer variety of raw timber waste. It includes old furniture such as chairs and closets as well as fence palings and pallets to name a few. Approximately 10-12% of this timber is contaminated and goes to landfill (Purcival, 2023). In this form, timber waste has little potential as a component of emergency housing due to the variance and bulk of the materials. However, with processing the waste can be converted into more usable forms.

Figure 19 – Mulched timber waste
Source: (O'Connor, 2023)

Figure 20 – Shredded timber waste
Source: (O'Connor, 2023)

The raw timber waste is processed on site and grinded down using a mulching machine. The most optimal result is when the timber is able to be reduced to fine mulch as shown in Figure 19. This is then stockpiled and once a month the members of the local community are allowed to come and collect one trailer load for free. This is a good environmental outcome as there is no waste in this instance – the waste is repurposed and reused with little environmental impact.

The timber that isn't able to be mulched down to compost is stored in a separate stockpile such as the one shown in Figure 20. Unlike the mulched timber waste, the shredded timber waste is unable to be repurposed and as a result it ends up in landfill. It can't even be used as firewood due to it being contaminated with treated timbers that have been processed with chemicals. Intuition from TRC representatives indicated that this waste source to have the most potential for use in emergency housing as it would be a good way to complete the environmental cycle on this waste stream.

Figure 21 – Raw C&D waste

Source: (O'Connor, 2023)

The C&D waste on site consisted of broken pieces of concrete and pipes as well as masonry and some steel. These materials are very common in the C&D industry and are a reliable waste stream for emergency housing.

Figure 22 – Crushed C&D waste

Source: (O'Connor, 2023)

The concrete is picked out from the pile of raw C&D waste and crushed on site to form aggregate. This aggregate is then used as road base in Zone A to make the driving paths more trafficable in wet weather. This is an effective way of repurposing the concrete as it makes the facility more accessible for all types of vehicles.

Figure 23 – Zilch Waste Recyclers collection bins
Source: (O'Connor, 2023)

Figure 24 – Scrap metal and white goods
Source: (O'Connor, 2023)

Collection bins as shown in Figure 23 are located next to the C&D waste stockpiles and they are loaded with bulky waste items to be collected by a company called Zilch Waste. This is a third-party company that has a contract with GTWMF to collect and utilise this waste for their own recycling endeavours. For the purpose of this study, this contract will be ignored and all C&D waste will be assessed for use in the design of emergency housing.

Scrap metal and white goods as shown in Figure 24 are the last waste items in Zone A. Some of the useful waste items in this section could include aluminium, tin, steel and electronic elements from white goods.

Figure 25 – Resource recovery area (Zone B)

Source: (O’Connor, 2023)

Figure 26 – Recycling collection bay

Source: (O’Connor, 2023)

Zone B is located in the north-western area of the facility. It is entirely under cover and out of the elements. Cars are able to drive right up to the waste stations and unload their waste.

The yellow skip bins as shown in Figure 26 are exactly the same as a normal yellow bin at home. They are used to dispose of cardboard, bottles and cans.

Figure 27 – Raw polystyrene collection bay

Source: (O’Connor, 2023)

Figure 28 – Polystyrene compactor conveyor belt

Source: (O’Connor, 2023)

Towards the back of Zone B there is a cage where people can dump polystyrene. The cage is quite large and is able to hold a large amount of polystyrene of all different shapes and sizes.

Next to the cage, there is a compactor that is responsible for breaking down the polystyrene into individual beads and then combining them with heat to produce a denser product. The compacted polystyrene briquettes are shown in Figure 30.

Figure 29 – Polystyrene compactor control unit, hopper and collection bin

Source: (O'Connor, 2023)

Figure 30 – Compacted polystyrene

Source: (O'Connor, 2023)

Figure 31 – Miscellaneous waste for landfill

Source: (O'Connor, 2023)

On the other side of Zone B there is a general miscellaneous waste station where all other waste goes. This is cleared regularly by excavators to keep it relatively clear and tidy. The waste is also sorted and sifted through to identify any items that have nothing wrong with them and have simply been thrown away due to people being wasteful. These items and collected and put aside to be later sold at the tip shop at the entrance of GTWMF.

Figure 32 – Mattresses for recycling

Source: (O’Connor, 2023)

GTWMF is one of the few waste management facilities to have a mattress recycling program in place. This involves stripping the mattresses down and recovering the steel inside them from the frame and springs.

3.2.2 Waste types at GTWMF

The following list of waste types is stored in the GTWMF database and represents all of the entries for 2022.

Table 4 – Waste types

Greater Toowoomba Waste Management Facility (GTWMF)		
Waste Types 2022		
Animals (Collection Contractor)	Disaster waste (COM)	Off-site transfer (processed timber)
Asbestos (DOM)	drumMUSTER	Off-site transfer to TS (greenwaste)
Asbestos (TRC)	Green waste (COM)	Processed concrete from RRA to LF
Asbestos to LF	Green waste (DOM)	Processed concrete from RRA2 to LF
Asphalt/bitumen	Househould mixed to LF	Processed concrete to RRA
BU waste incoming (from Cecil Plains TS)	Household mixed to TS (nonweighed)	Processed concrete to RRA2
BU waste incoming (from Cooyar/Evergreen TS)	Illegally dumped waste	Processed mulch from RRA to LF
BU waste incoming (from Crows Nest TS)	Kerbside waste collection	Processed mulch incoming to LF
BU waste incoming (from Emu Creek TS)	Kerbside waste collection regional	Processed mulch incoming to RRA
BU waste incoming (from GTWMF TS)	Kerbside green waste collection	Processed timber from RRA to LF
BU waste incoming (from Kleinton TS)	Kerbside mulch - to OPS use (general)	Processed timber incoming to LF
BU waste incoming (from Millmerran bin sites)	Large whitegoods (COM)	Processed timber incoming to RRA
BU waste incoming (from Oakey TS)	Large whitegoods (DOM)	Receival (concrete from GTWMF to LF)
BU waste incoming (from Ravensbourne TS)	LG parks waste	Receival (concrete from Kleinton)
BU waste incoming (from Yarraman green waste)	LG parks waste (JJ Richard)	Receival (green waste from another site)
BU waste incoming (from Yarraman)	Mattresses (COM) (for deemed sites)	Receival (green waste from Oakey)
BU waste outgoing (from Crows Nest TS)	Mattresses (DOM)	Receival (green waste from Ravensbourne)
BU waste outgoing (from GTWMF TS)	Millmerran fly ash	Receival (recyclables from Ravensbourne)
BU waste outgoing (from Kleinton TS)	Mixed commercial Jondaryan	Receival (scrap metal from Ravensbourne)
BU waste outgoing (from Oakey TS)	Mixed commercial Jondy (car to LT COM)	Recovered materials from RRA to tip shop
Builders waste (COM)	Mixed commercial Tier 5	Recyclables (COM)
Charity waste with exemption	Mixed waste (COM) to LF	Recyclables (DOM)
Charity waste with exemption + recyclables	Mixed waste (COM) to LF + recyclables	Regulated waste
Clean earth from paddock (Millmerran)	Mixed waste (COM) to TS	Regulated waste (special burial)
Clean fill (COM) to LF	Mixed waste (COM) to TS + recyclables	Scrap metal steel (COM)
Clean fill (COM) to RRA	Mixed waste (relocated LGI)	Scrap metal steel (DOM)
Clean fill (DOM) to RRA	Mixed waste admin	Scrap metal non-ferrous (COM)
Clean fill from cell EF to LF	Mt Kynoch treatment slurry	Scrap metal non-ferrous (DOM)
Clean fill from cell EF to RRA2	Non waste (fuel new building ETC)	Special burial other (COM)
Clean fill from RRA to LF	Off-site disposal (asbestos)	Storm damage Jan 2022 (COM)
Clean fill to cell EF	Off-site disposal (batteries)	Storm damage Jan 2022 (DOM)
Clean Up Australia Day	Off-site disposal (cardboard from TRC)	Street clean
Concrete bricks (COM)	Off-site disposal (EPS)	Timber or pallets (COM)
Concrete bricks (DOM)	Off-site disposal (E-waste)	Timber or pallets (DOM)
Contaminated soil (C+M) regulated	Off-site disposal (fire extinguishers)	Tip shop waste
Contaminated soil (disposal permit)	Off-site disposal (free mulch)	Transfer (green waste to another site)
Contaminated soil (special burial)	Off-site disposal (gas bottles)	Transfer (clean fill to another site)
Contaminated soil to LF	Off-site disposal (hazardous)	Trash and treasure customers
Councils non TRC disaster waste	Off-site disposal (mixed plastics)	Treated timber (INC CCA)
Cover material (COM) to LF	Off-site disposal (mixed recyclate)	Tyres (COM)
Dead animals < 50kg (COM)	Off-site disposal (non-ferrous)	Tyres (DOM)
Dead animals < 50kg (DOM)	Off-site disposal (paint)	Tyres (TRC)
Dead animals 200-1000kg (COM)	Off-site disposal (processed concrete)	X cover material (DOM) to LF
Dead animals 200-1000kg (DOM)	Off-site disposal (steel)	Z (DOM) concrete
Dead animals 50-200kg (COM)	Off-site disposal (tyres)	Z (DOM) dead animals
Dead animals 50-200kg (DOM)	Off-site Kleinton water	Z (DOM) green waste
Dead animals bulk (COM)	Off-site transfer (clean fill)	Z (DOM) household mixed
Dead animals bulk (DOM)	Off-site transfer (drumMUSTER)	Z (DOM) household mixed + recyclables
Dead animals > 1000kg (COM)	Off-site transfer (mulch)	Z (DOM) timber or pallets
Dead animals > 1000kg (DOM)	Off-site transfer (oil)	

3.2.3 Waste processing at GTWMF

Once the waste is collected and brought to GTWMF, it needs to be processed and sorted accordingly. The waste and recycling snapshot seen in Figure 33 effectively breaks down the details of waste collection in the Toowoomba region. Of particular note is the amount of mixed plastics (494.91 tonnes), steel (138.14 tonnes) and aluminium (76.36 tonnes) that is collected via kerbside recycling. Another key statistic is that the total amount of waste collected is 158,214 tonnes, however only 70,515 or 45% of it is diverted from landfill. Hence, there are a lot of potential resources that are being sent to landfill. Finally, there is approximately 362 tonnes of free mulch that is given away annually across all waste management facilities in the Toowoomba region.

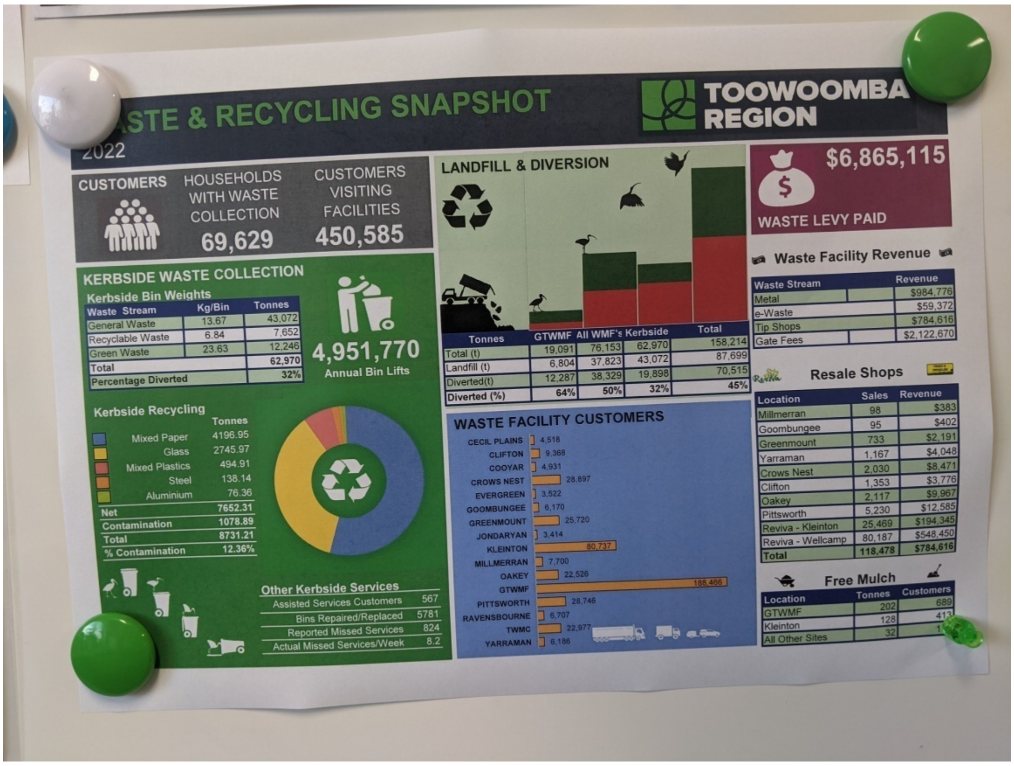

Figure 33 – Breakdown of waste processing at GTWMF in 2022

Source: (O’Connor, 2023)

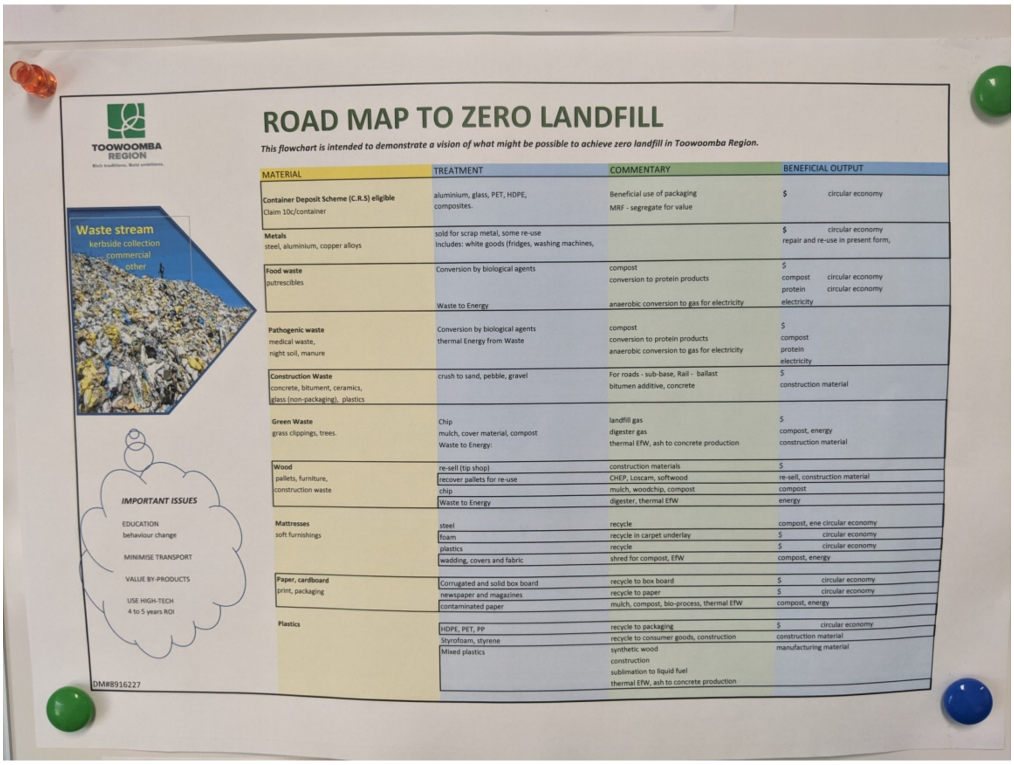

Figure 34 – Road map to zero landfill

Source: (O’Connor, 2023)

As there is still a fair amount of waste going to landfill, GTWMF has a road map to zero landfill which can be seen in Figure 34. The flow chart highlights some of the major waste materials that are collected and proposes a variety of ways to treat them so as to recycle them and reinject them as circular products. Some of the more relevant commentaries for this project include the reuse of mattresses in carpet underlay, recycling wood and using mixed plastics to create synthetic wood.

3.3 Concept design

The original inspiration for this project was to design an emergency housing model using unwanted plastic rainwater tanks as the shell structure for the house. However, the potential contact who was offering the tanks moved away from the area and as a result they are no longer a viable option. Despite this, the plan is to still run with a rainwater tank as the formal base structure of the emergency housing model. As this is only a concept design, the cost of these rainwater tanks will be ignored in the cost evaluation as we will just assume that the tanks were provided as originally planned. However, for the sake of conservatism, the retail cost of the tanks will be included in the final cost analysis.

3.3.1 Autodesk AutoCAD

Most engineering applications in today's society have some, if not total, dependence on technology in the form of computer software packages. One of the biggest, most renowned software packages is AutoCAD, an Autodesk product. AutoCAD is a powerful drafting and design tool that has been used by architects, engineers and construction professionals since its introduction in 1982 (Autodesk, n.d.).

Some of the important uses of AutoCAD as outlined in Autodesk's product overview:

- "Design and annotate 2D geometry and 3D models with solids, surfaces and mesh objects
- Automate tasks such as comparing drawings, replacing blocks, counting objects, creating schedules and more

- Create a customised workspace to maximise productivity with add-on apps and APIs" (Autodesk, n.d.)

For the purpose of this project, AutoCAD will be used as the primary software package to develop the initial concept design. As it is just a concept level design at this stage, the only important factors to include are critical design requirements such as minimum floor area and head clearance. Hence, AutoCAD will be used to draw these physical attributes accurately and provide a visual representation of the design, albeit in the form of 2D sections.

3.3.2 Design sketches

The following design sketches were created in AutoCAD as a rough first attempt at what the emergency housing model would look like using a rainwater tank as the base structure.

Figure 35 – Proposed rainwater tank for use as base structure

Source: (The Tank Factory, n.d.)

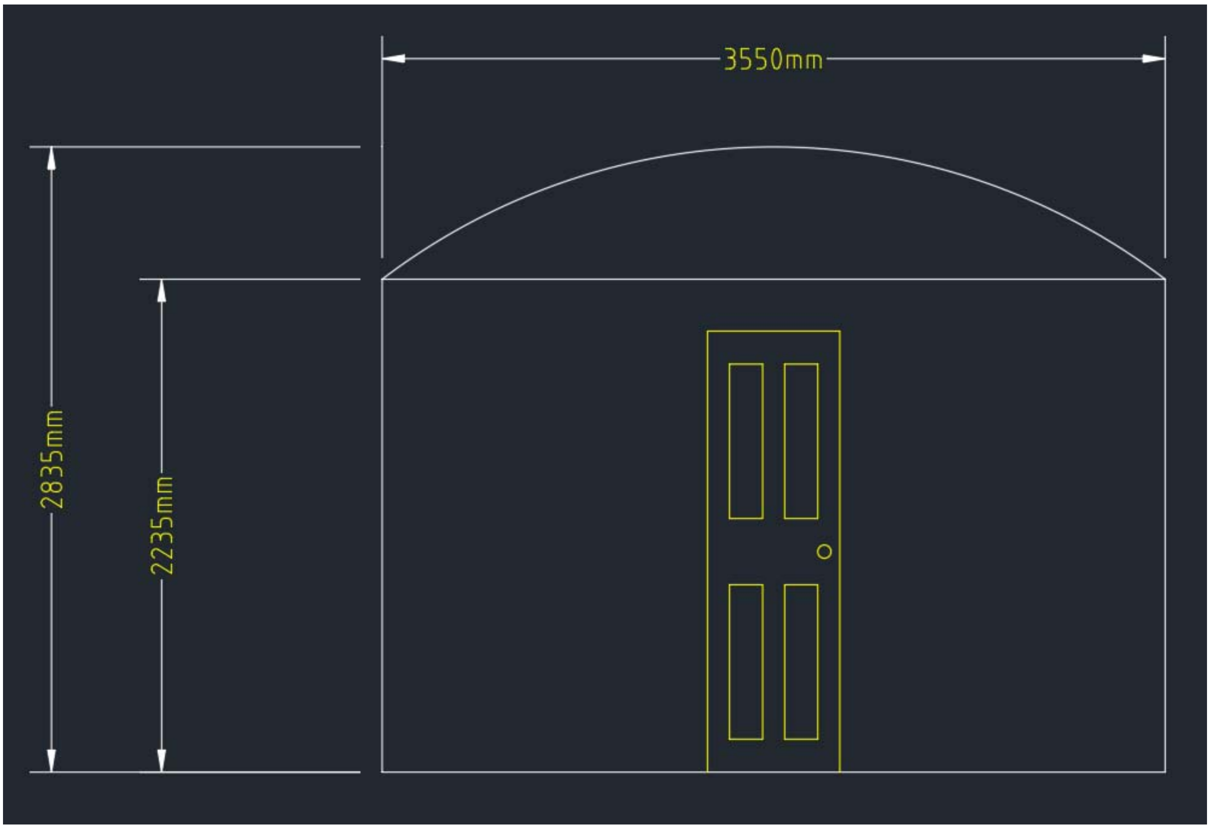

Figure 36 – Front view of RTEHM

The proposed rainwater tank is an R 22,700 Litre / 5000 gallon upright rainwater tank produced by The Tank Factory. Although this company operates out of Alstonville, NSW, Toowoomba falls within its standard freight area. This exact tank was chosen due to its sufficient floor space and height clearance. If the cost of the tank was to be included in the analysis, it is also an affordable option at $3195 RRP. This tank is actually the company's most popular model and they manufacture over 45 per week so it is definitely a sustainable material source (The Tank Factory, n.d.).

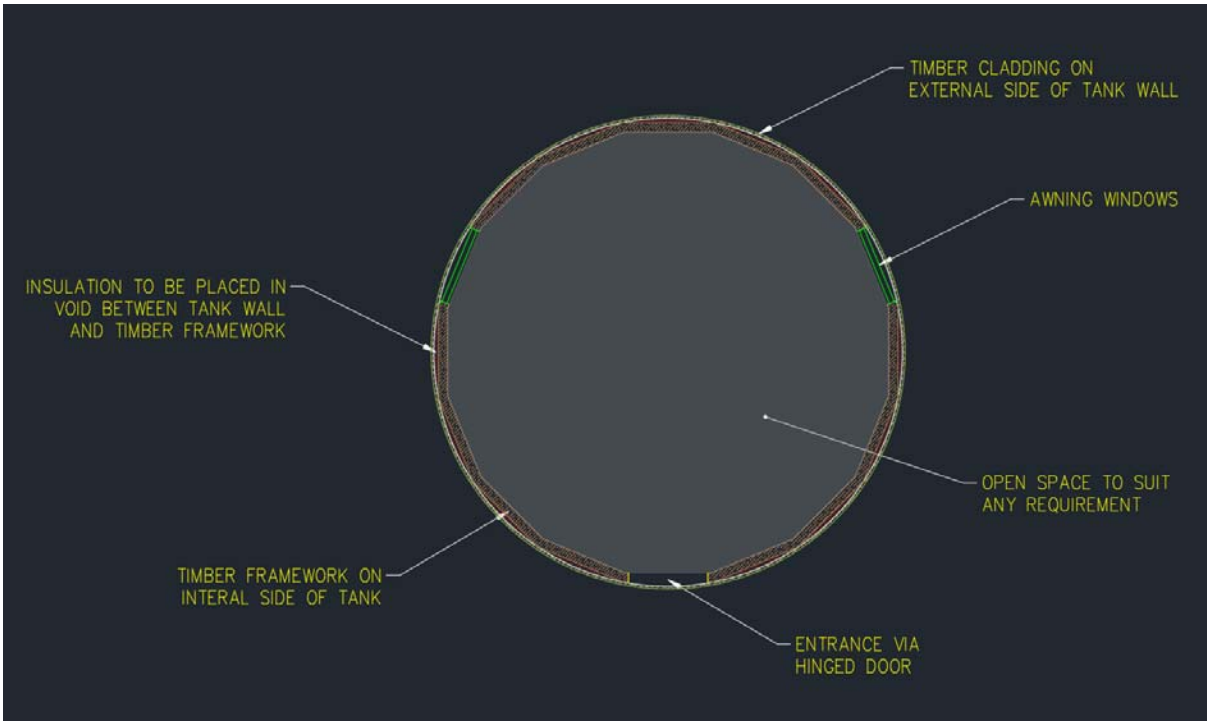

Figure 37 – Top view of rainwater tank emergency housing model

With the base structure selected, it needs to be equipped with all of the appropriate fittings and furnishings to make it a liveable space. Figure 37 above provides a basic layout of the RTEHM. The materials used for the timber cladding and framework, insulation and potentially even doors and windows will need to be sourced from C&D waste wherever possible.

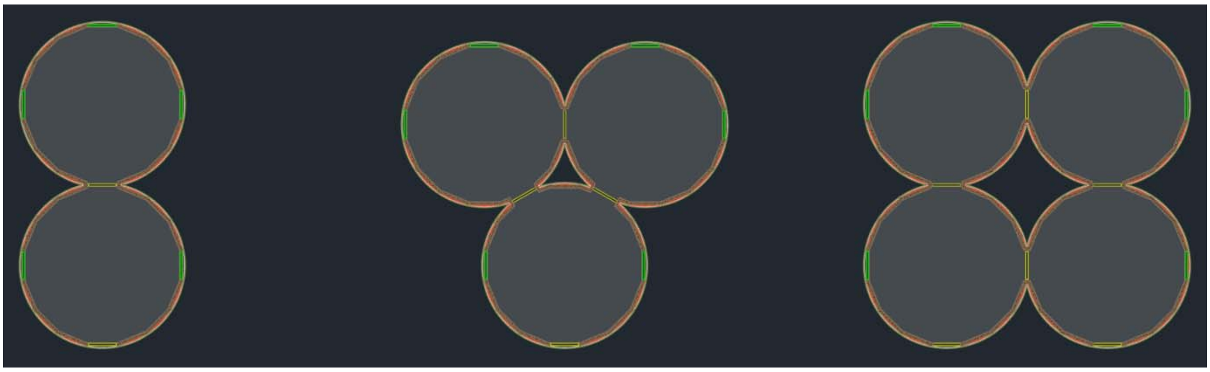

Figure 38 – Modularised configurations of RTEHM

A single rainwater tank will only have a nominal floor area of 8 square metres and as such will not be large enough to house all of the specific requirements as per QDC MP 3.3. The following items need to be accounted for in the overall design:

- Sleeping compartments;
- Outdoor amenity (*not included in the scope for this design*);
- Bathing and sanitary facilities;
- Laundry;
- Kitchen;
- Storage facilities.

There needs to be scope to include all of these items in a single design if they are to function as a self contained dwelling. On the other hand, they can also be set up in a communal environment such as the pod village in Wollongbar (NSW Government, 2023). In this instance, the rainwater tanks can be set up for specific purposes i.e. communal bathrooms, kitchens and laundries. Regardless of what approach is taken, a modular design would allow for a variety of uses in a number of different applications.

3.3.3 Material list

In regards to fitting out the rainwater tanks, a number of the waste types were considered but there were a few that stood out as suitable materials. A shortlist of materials was highlighted with their purposes as follows:

- Recycled timber could be used for framing, timber cladding or flooring to produce extra heat and sound insulation;
- Crushed concrete used as an aggregate in forming new concrete for foundations;
- Condensed polystyrene can be used as insulation;
- Aluminium cans could also be used as insulation;
- White goods could be repaired and reused;
- Electronics could be stripped down for parts and used to create solar panels to run small interior appliances;
- Steel could be used to make window frames.

The main considerations in choosing the right materials will be largely dependent on factors such as weight, cost for processing and availability.

3.4 Initial cost analysis

Perhaps the most important consideration of any emergency housing model, or any construction project for that matter, is the total cost of the materials and labour to build it. The cost determines the margins for a project and plays a major role when it comes to making decisions about design elements. At this stage of the design, although the specific details haven't been selected, it is important to get an initial cost estimate to determine whether the project is viable or not.

One of the methods of getting cost estimates in the construction industry is by accessing the Rawlinsons Construction Cost Guide. Rawlinsons is a company that annually publishes up to date comprehensive pricing information for construction costs across all states and territories in Australia. They provide an Australian Construction Handbook which is relevant for larger scale, complex building projects in excess of $1.5 million as well as the aforementioned Construction Cost Guide which targets smaller scale residential, commercial and industrial projects under $1.5 million (Rawlinsons, n.d.).

When looking at the Construction Cost Guide, there are two methods to look at the breakdown of the costs. The first one is to obtain a blanket estimate of the building costs per square metre of floor area between inner faces of external walls. The breakdown of the costs for this method can be seen in Table 5. Alternatively, the other method for estimating the building costs is to assess the structure by its individual elements and find out their costs. The breakdown of the costs for this method can be seen in Table 6.

Table 5 – Residential housing costs per floor area

13.0 RESIDENTIAL

	Costs exclude the Goods and Services Tax (G.S.T.).	...	Note						
	The costs given hereafter are based on the total floor area between inner faces of external walls. To adjust for measurement based on outer face of external walls REDUCE the following Houses- single unit/costs per square metre by approximately 10%	...	Note						
13.1	HOUSES - SINGLE UNIT								
13.1.1	PROJECT HOUSE - tiled roof and built on a flat site :								
	Basic standard finish -								
13.1.1.1	90/110sqm :								
	Brick veneer	...	sqm	950-1025	1150-1240	1435-1545	1185-1280	960-1030	1265-1365
13.1.1.2	Full brick	...	sqm	1025-1105	1250-1345	1550-1670	1260-1360	975-1055	1295-1395
13.1.1.3	120/140sqm :								
	Brick veneer	...	sqm	890-960	1095-1180	1400-1510	1160-1250	920-995	1215-1310
13.1.1.4	Full brick	...	sqm	950-1025	1215-1305	1500-1615	1250-1350	945-1015	1270-1370
	Medium standard finish -								
13.1.1.5	120/140sqm :								
	Brick veneer	...	sqm	1035-1115	1310-1410	1565-1690	1340-1445	1020-1100	1395-1500
13.1.1.6	Full brick	...	sqm	1100-1190	1405-1515	1690-1820	1430-1540	1060-1140	1430-1540
13.1.1.7	160/190sqm :								
	Brick veneer	...	sqm	1000-1075	1265-1360	1435-1545	1295-1395	975-1055	1365-1470
13.1.1.8	Full brick	...	sqm	1075-1160	1395-1505	1555-1675	1410-1520	1015-1090	1385-1490
13.1.2	INDIVIDUAL HOUSE - tiled roof, approximately 150/350sqm :								
	Medium standard finish -								
13.1.2.1	Framed	...	sqm	1130-1220	1560-1680	1825-1970	1465-1580	1495-1610	1815-1955
13.2.2.2	Brick veneer	...	sqm	1225-1325	1715-1845	1950-2100	1640-1765	1650-1775	1965-2120
13.1.2.3	Full brick	...	sqm	1275-1375	1870-2015	2085-2250	1730-1865	1745-1885	2050-2210
	High standard finish, no air-conditioning -								
13.1.2.4	Framed	...	sqm	1635-1765	2265-2440	2365-2550	2120-2285	-	2505-2700
13.1.2.5	Brick veneer	...	sqm	1760-1895	2535-2730	2525-2720	2305-2485	-	2745-2960
13.1.2.6	Full brick	...	sqm	1830-1975	2680-2885	2635-2840	2435-2620	2500-2695	2815-3035
	Prestige standard, partial air-conditioning -								
13.1.2.7	Full brick	...	sqm	2395-2580	3485-3755	3495-3765	3060-3300	3350-3615	3625-3905
13.1.2.8	Prestige standard, top of the range	...	up to +100%						
13.1.2.9	Verandah - ground floor level comprising, ground floor timber framing, decking, timber balustrade, timber posts, roof tile of exposed timber rafters	...	sqm	435-470	545-590	535-575	480-515	520-560	565-610

Source: (Rawlinsons Construction Cost Guide, 2021)

Table 6 – Residential housing costs per individual element

13.0 **RESIDENTIAL**

	13.1.2.1 Individual House Medium Std. Framed		13.1.2.2 Individual House Medium Std. Brick Veneer		13.1.2.3 Individual House Medium Std. Full Brick		13.1.2.4 Individual House High Std. Framed	
	$/sqm	%	$/sqm	%	$/sqm	%	$/sqm	%
PRELIMINARIES	191.00	10.1	207.25	10.1	219.25	10.3	268.00	10.3
SUBSTRUCTURE	149.25	7.9	167.50	8.2	177.75	8.3	156.00	6.0
SUPERSTRUCTURE								
Columns	-	-	-	-	-	-	-	-
Upper Floors	-	-	-	-	-	-	-	-
Staircase	-	-	-	-	-	-	-	-
Roof	283.00	15.0	283.25	13.9	282.25	13.3	351.25	13.5
External Walls)	331.25	17.6	435.75	21.3	456.50	21.4	402.75	15.5
Windows)								
External Doors	35.50	1.9	36.00	1.8	35.75	1.7	46.25	1.8
Internal Walls	111.75	5.9	123.25	6.0	124.75	5.9	147.50	5.6
Internal Screens	12.25	0.7	15.50	0.8	15.50	0.7	21.00	0.8
Internal Doors	55.00	2.9	55.25	2.7	54.75	2.6	71.25	2.7
FINISHES								
Wall	61.50	3.3	60.75	3.0	105.25	4.9	83.50	3.2
Floor	45.75	2.4	45.75	2.2	46.00	2.2	145.00	5.6
Ceiling	88.75	4.7	89.00	4.4	87.00	4.1	123.00	4.7
FITTINGS								
Fitments	145.00	7.7	146.00	7.1	144.75	6.8	294.00	11.3
Special	-	-	-	-	-	-	-	-
SERVICES								
Plumbing	233.25	12.4	234.00	11.4	232.75	10.9	289.00	11.1
Mechanical	-	-	-	-	-	-	-	-
Fire	-	-	-	-	-	-	-	-
Electrical	79.75	4.2	79.75	3.9	79.75	3.7	126.50	4.8
Transportation	-	-	-	-	-	-	-	-
Special	-	-	-	-	-	-	-	-
EXTERNAL SERVICES	14.75	0.8	14.75	0.7	14.75	0.7	14.75	0.6
CONTINGENCY	47.25	2.5	51.25	2.5	53.25	2.5	65.25	2.5
TOTAL (Mean cost - SYDNEY)	1885.00	100.0	2045.00	100.0	2130.00	100.0	2605.00	100.0

Source: (Rawlinsons Construction Cost Guide, 2021)

As the design is only conceptual at this stage, it is impossible to get an accurate building cost estimate for the RTEHM by breaking it down into individual elements. Not only would this be based on a number of assumptions, but the selection of materials and final quantities is yet to be determined so there is little value in using this method as it all could change once detailed design is undertaken. Hence, the more appropriate building cost estimate method would be the former which only requires an internal floor area. Based on the dimensions of the tank (1.775 m external diameter) and accommodating for internal walls which are inscribed inside the circular shape of the tank, the floor area is calculated to nominally be:

$$A = \pi r^2 = \pi \times 1.6^2 = 8.04 \text{ m}^2 \approx 8 \text{ m}^2$$

Using this floor area as the base parameter for the building cost estimate, the Brisbane pricing range was adopted due to locality. The Rawlinsons Construction Cost Guide 2021 was used and the findings were as follows:

Table 7 – RTEHM building cost estimate for base structure

Line Item	Description	Rate	Cost
13.1.2.10	PREFABRICATED HOUSE Colour coated corrugated steel external skin with plywood internal skin. Medium standard finish, 70/90 sqm	\$1405 - \$1500 sqm	\$12,000
or			
13.4.1.2	HOLIDAY UNITS Transportable type, basic standard finish, approximately 70/90 sqm	\$1000 - \$1075 sqm	\$8600

Note: The highest value in each price range was selected to be conservative.

Although the RTEHM would fall under the category of a prefabricated dwelling, it also can be classified as a transportable dwelling. It is also worth mentioning that the sizes of the structures in the estimate quote are significantly larger than what the proposed RTEHM is. This may very well change the value of the applicable rate but until further design is completed there isn't any way to gain a more accurate building cost estimate. As such, in the name of conservatism, the prefabricated house building cost will be adopted for the initial cost estimate.

Beyond the base structure, the costs of any additional fixtures also need to be included in the building cost estimate. As per QDC MP 3.3, this includes a verandah with a minimum floor area of 4.5 square metres. Using the same methodology as above for the base structure, the findings were as follows:

Table 8 – RTEHM building cost estimate for additional fixtures

Line Item	Description	Rate	Cost
13.1.2.9	Verandah – ground floor level comprising, ground floor timber framing, decking, timber balustrade, timber posts, roof tile of exposed timber rafters	$545 - $590 sqm	$2655
13.1.3.7	Bathroom fit-out and services	$24,500 - $28,000 each	$28,000
13.1.3.8	Kitchen fit-out and services	$20,500 - $23,500 each	$23,500

Note: The highest value in each price range was selected to be conservative.

With the established building cost estimates for the base structure as well as any additional fixtures, a total building cost estimate can be generated for each modular size of the RTEHM based on a typical layout.

Table 9 – Total building cost estimate

Number of modules	Allocation of modules	Cost
1	1 x bedroom / living room	$12,000
	1 x verandah	$2655
Total		**$14,655**
2	1 x bedroom / living room	$12,000
	1 x bathroom	$28,000
	1 x verandah	$2655
Total		**$42,655**
3	1 x bedroom / living room	$12,000
	1 x bathroom	$28,000
	1 x kitchen	$23,500
	1 x verandah	$2655
Total		**$66,155**

4	2 x bedroom / living room	$24,000
	1 x bathroom	$28,000
	1 x kitchen	$23,500
	1 x verandah	$2655
Total		**$78,155**

The costs illustrated in Table 9 are within the margins of what is seen in the market currently. Granted, this assessment of the costs is very conservative as it is to normal housing standards, not emergency housing standards. Another key consideration in the initial costs is that all of the rates are assuming the use of new materials. Obviously, the aim of this project is to use C&D waste materials to build the emergency housing which should reduce the overall cost significantly more depending on the processing required to reuse for the recycled materials.

3.5 Feasibility assessment

With an initial cost estimate, the next step is to perform a feasibility assessment to determine if the project is able to be achieved in a real world setting and if it is affordable to construct. The best way to do this is to assess the design's viability according to these factors:

- Cost
- Ease of assembly
- Transportability
- Sustainability
- Comparison to existing models

3.5.1 Cost

The cost of the materials to construct the RTEHM is very much dependent on the processing costs involved in reclaiming waste resources. The cost of processing waste materials is directly related to the amount of time it takes an individual or team of people to sift through it. Table 10 below provides a rough estimate for the costs associated with the processing of timber and concrete.

Table 10 – Costs of C&D waste recycling

Material	Action	Cost ($/tonne)
Timber	Sorting	40-126
	Chipping	20
Concrete	Sorting	7
	Preparation	4
	Crushing	8

Source: (Ministry for the Environment, 2007)

Assuming the nominal weight of timber per module to be approximately 500 kg, this places the cost of timber at $60 for each module. Of course, this would be subject to a more thorough review for the specific case of GTWMF. It is clear to see that recycling C&D waste is significantly more cost effective than using new materials which would cost thousands of dollars as evidenced by the pricing of the modules by Rawlinsons.

Despite the obvious benefits of using recycled C&D waste, for the purpose of the cost comparison the Rawlinsons building cost estimates will be used in an attempt to match the likeness of new materials.

The single module unit can be best compared to both the Boxabl tiny homes and the pods. An unfurnished single module unit with a verandah will cost $14,655 yet a Casita model Boxabl tiny home will cost nearly $80,000, albeit furnished. On the other hand, the pods come fully furnished for approximately $30,000. Even once the furnishings are included for a bedroom / living room module, the final cost will still be less than both of the existing temporary housing models mentioned.

At the other end of the scale, the four module unit that comes equipped with two bedrooms, a kitchen, a bathroom and a verandah comes in at $78,155 with only the bedrooms in need of furnishing. To replicate the same setup with the Boxabl tiny homes, you would need to provide four Casita models which would cost in excess of $240,000. The next best comparison is to VanHomes which boasts a similar sized product for $88,320. However, this only includes the fit-out for the internal plumbing and storage space.

Hence, it can be seen that even when accommodating for the use of new materials in the construction of the RTEHM, it is competitive with what is already out there in the market. Once some of these materials are substituted for recycled C&D waste materials this cost is going to reduce significantly and make the design even more feasible.

3.5.2 Ease of assembly

The existing temporary housing models promote how simple their products are to assemble out in the field but this is only possible because they have been prefabricated in a factory. Whether they are assembled using technology or by manual labour, the ease of assembly is improved at the cost of compromising the input costs in the construction stage. The beauty of the RTEHM is that it can be built entirely on site from raw materials or it can have certain elements such as the wall panels prefabricated to streamline the assembly process.

The best design factor of the RTEHM is that it is inherently a rainwater tank which means that it is easy to manoeuvre and place on site with minimal effort and coordination. Rainwater tanks are typically delivered to a site on the back of a tray truck and rolled to their final location by a team of individuals. In some instances where the terrain is unsuitable for this, it is also easy to move them by using a crane to lift them and put them in place as seen in Figure 39. However, for most applications of emergency housing, the sites chosen will be on flat terrain such as sporting fields so the former method of rolling them will be the easiest and cheapest way to position them.

Figure 39 – Crane lifting rainwater tank

Source: (The Water Tank Factory, n.d.)

3.5.3 Transportability

As previously mentioned, the rainwater tanks are able to be transported by using standard service vehicles such as a tray truck. This simplifies the procedure of transporting the emergency housing model significantly in comparison to prefabricated tiny homes such as Boxabl's Casita model which requires a specifically designed articulated trailer or a heavy class vehicle.

Similarly, any prefabricated elements such as wall panels, windows, doors or any other internal fit-out object can be transported using standard service vehicles also. This would be the case where the RTEHM are to be assembled on site. However, if the prefabricated route is chosen, the models can simply be lifted on and off the service vehicles by using a crane.

3.5.4 Sustainability

As the RTEHM is anticipated to be constructed from recycled C&D waste materials, the design contributes to a circular economy by repurposing said materials. This is a sustainable practice that will lead to less waste materials in landfill as well as reduce the amount of new materials used.

In regards to the sustainability of the RTEHM, Table 11 below states the expected design life of the materials used to create it.

Table 11 – Design life of RTEHM materials

Material	Design life
Polyethylene (rainwater tank)	10 to 20 years [1]
Timber (wall frames, cladding, decking)	15 years [2]
Aggregate concrete (foundation)	50 years [3]
Polystyrene (insulation)	Indefinite [4]
Steel (window frames)	10 to 20 years [5]

Sources: (Tankworld, 2023) [1]; (QTimber, 2017) [2]; (Zhu et al., 2019) [3]; (Corder, 2015) [4]; (Metro Steel Windows & Door, 2022) [5]

The materials that make up the components of the RTEHM have a minimum design life of 10 years. Based on the above estimations, the expected design life of this model would be approximately 15 years, which would service a number of people in that period of time.

3.5.5 Comparison to existing models

The best way to see how the RTEHM compares to the existing temporary housing models is to assess it against the same criteria used in Chapter 2.

Table 12 – Decision matrix for evaluating existing and design temporary housing models

Temporary housing model	Prefabricated modular tiny homes (Boxabl)	Mobile tiny homes (VanHomes / Aussie Tiny Houses)	Pods (Minderoo pods / Hutchinson modules)	RTEHM (Project design)
Cost	3	2	5	4

Size	4	4	2	3
Modularisation	5	2	1	5
Ease of assembly	3	3	4	3
Transportability	3	3	3	4
Sustainability	4	3	3	5
Total	**22**	**17**	**18**	**24**

Key:

1	Poor
2	Unsatisfactory
3	Satisfactory
4	Very satisfactory
5	Outstanding

The RTEHM compares favourably to the existing temporary housing models as it is able to effectively incorporate the best parts of all of them. For example, the modularisation of the Boxabl tiny homes is replicated in the proposed design yet it is achieved at a lower cost and without compromising any of the other criteria.

Chapter 4 – Final Design

4.1 Detailed design

With a working concept model in place, the next step is to flesh out the design in more depth. This section of the dissertation focuses on experimenting with the base design to come up with a detailed design that is practical, efficient and ethical.

4.1.1 Design workflow

In order to develop a detailed design that ticks all of the legislative boxes, the design needs to be built from the ground up. Figure 40 below shows the different steps and components to be considered in the design process.

Figure 40 – Detailed design flow chart

By developing a detailed design using this process, the intention is to come up with a tangible product that fits within the context of the original aims and objectives. To recap, this included the following items as discussed in Chapter 1:

Aims:

- *Use environmentally friendly C&D materials i.e. no asbestos, treated pine etc.;*
- *Build as much of the emergency housing model from C&D waste materials as possible;*
- *Create a holistic design that can be produced in multiple locations and in multiple configurations;*
- *Design the emergency housing model so that it is easy to assemble with a small team of people within a short timeframe.*

Objectives:

- *Design an emergency housing model for under $30,000;*
- *Emergency housing modules to be less than 1000 kg.*

These aims and objectives will be at the forefront of any decision making that goes into designing the RTEHM. The aims are general aspirations for the design whereas the objectives are viewed as added bonuses and tertiary benchmarks to hit for design efficiency but they aren't limiting factors to the design.

4.1.2 Autodesk Revit

AutoCAD was used for the initial concept design as it is a simple product that is easy to use and draft in 2D. However, for the detailed design it is more effective to use a building information modelling (BIM) software package to design all the elements of the RTEHM in 3D. As such, another Autodesk product called Revit was selected to undertake the design. Revit was introduced in 2000 and is one of the leading BIM softwares in the world and is widely used by professionals in the architectural, engineering and construction industries alike (Cho, 2021).

Some of the important uses of Revit as outlined in Autodesk's product overview:

- "Model shapes, structures and systems in 3D with parametric accuracy, precision and ease
- Streamline project management with instant revisions to plans, elevations, schedules, sections and sheets
- Unite multidisciplinary project teams for higher efficiency, collaboration and impact in the office or on the construction site"
  (Autodesk, n.d.)

The most important factor in deciding to use BIM software for the detailed design is its ability to produce a list of materials and their respective quantities. This ensures that every component in the design is accounted for and the physical attributes are able to be recalled for production purposes.

4.1.3 Temporary accommodation buildings requirements

Now that the base structure has been determined, the next step is to determine what the requirements are for temporary accommodation buildings as per QDC MP 3.3. It is worth noting that there are different sets of requirements depending on the application of the accommodation as well as the duration of time that the buildings will be used for. These conditions are specified in Table T1 of QDC MP 3.3 as shown below in Table 13.

Table 13 – Applicable performance criteria for different accommodation arrangements

Period of intended or approved use	Application of performance criteria of this code
Accommodation where there is an employment agreement or where a rent is paid	
42 *days* or less.	P20.
More than 42 *days*.	All criteria except P20.
Temporary accommodation buildings in lawful use on the day this code commences that are moved to a new site once within a two year period from the commencement date of this code.	For buildings intended or approved for use on site for up to (a) 112 *days* – P20; and (b) more than 112 *days* - All criteria except P2, P3, P5, P6 and P7.
Accommodation for private and domestic residential use	
Temporary accommodation buildings intended for uses specified in (3) (c).	P1 and P3.

Source: (Department of Housing, 2014)

There are 20 performance criterions that cover all of the accommodation arrangements. Accommodation that is used for employment or rental purposes and is on site for more than 42 days has to meet all code requirements however if it is just to be used for 42 days or less it only needs to meet basic standards of structural adequacy, health and amenity and also fire and life safety. On the other hand, accommodation for private and domestic residential use need only satisfy certain sections and parts of the BCA (Queensland Government, n.d.). Table 14 below outlines the requirements for each performance criterion.

Table 14 – Temporary accommodation buildings performance criteria

Performance Criteria	Requirements	Comments Red = Requires action
Building Standards		
P1 **Removal or demolition**	*Temporary accommodation buildings, after an approved duration of no more than 24 months, are removed from the site or demolished.*	RTEHM is only intended to be used as an emergency response, not a permanent solution.
P2 **Building Code of Australia**	*Temporary accommodations buildings where there is an employment agreement or where rent is paid and are:*	
	(a) class 2 to 9 buildings need to comply with the following provisions of the BCA Volume 1: *(i) sections A to I;* *(ii) parts J1.1 to J1.5.*	Not applicable as the RTEHM is a class 1 building (NCC, 2022).
	(b) class 1 or 10 buildings need to comply with the following provisions of the BCA Volume 2: *(i) section 1 and parts 3.0 to 3.11;* *(ii) 3.12.1.1 to 3.12.1.4 and 3.12.1.6.*	These provisions of the BCA would need to be adhered to if at some point the RTEHM were to be utilised as accommodation for workers or tenants.
P3 **Building Code of Australia**	*Temporary accommodations buildings which are used for private and domestic residential use and are:*	
	(a) class 2 to 9 buildings need to comply with the following provisions of the BCA Volume 1: *(i) sections A to E and sections G to I;* *(ii) parts F1 to P4 and parts J1.1 to J1.5.*	Not applicable as the RTEHM is a class 1 building (NCC, 2022).
	(b) class 1 or 10 buildings need to comply with the following provisions of the BCA Volume 2: *(i) section 1, parts 3.0 to 3.7 and 3.9 to 3.11;* *(ii) parts 3.8.1 to 3.8.5, 3.12.1.1 to*	As the RTEHM is intended for private and domestic residential use, these provisions of the BCA need to be followed during design and construction.

Performance Criteria	Requirements	Comments **Red = Requires action**
	3.12.1.4 and 3.12.1.6.	
Health and Amenity		
P4 **Siting**	*Has the temporary accommodation building been:*	
	(a) placed on a base of concrete, coarse gravel or similar base material;	To be completed on site.
	(b) raised at least 150 mm above the surrounding ground level;	To be completed on site.
	(c) placed at least 45 metres away from work activities (other than catering for or maintenance of temporary accommodation buildings) on site?	To be completed on site.
P5 **Sleeping compartments**	*Has the sleeping compartment been provided with:*	
	(a) a double power point;	Need to include in design.
	(b) walls extending from the floor to the ceiling separating each sleeping compartment;	Need to include in design.
	(c) a minimum floor area of 5.6 m^2 for each bed?	Need to include in design.
P6 **Finishing**	*Are internal walls of the buildings lined with fibre cement sheeting, plasterboard, timber or the like?*	Need to include in design.
P7 **Pest control**	*Is the building air conditioned?*	Will not be included in this design but can be added at a later date.
	If the building is not air conditioned, does every door and window (other than a door, window or other opening from a sleeping compartment to a screened verandah) of a sleeping compartment or shared facility have flyscreens?	Need to include in design.
P8 **Dust control**	*Is the ground surrounding the temporary accommodation building sealed or does the*	To be completed on site.

Performance Criteria	Requirements	Comments Red = Requires action
	first 6 metres have ground cover such as mulch or coarse aggregate?	
P9 **Vehicle access**	*If the temporary accommodation building has an approval period of more than six months or more than 100 beds, are on-site roads, driveways, vehicle circulation areas and parking bays in accordance with AS 2890.1 – 1993?*	To be completed on site.
P10 **Outdoor amenity**	*Does each sleeping compartment have an outdoor area with a sealed floor protected from the weather by a roof?*	Need to include in design.
	Do the sleeping compartments:	
	(a) have access to an outdoor space, within 45 metres from the entry door of a sleeping compartment, with a floor area of not less than 30 m² for every 20 sleeping compartments or part thereof;	Need to include in design.
	(b) face each other and are less than 3 metres apart, have a verandah attached to the temporary accommodation building with a floor area of not less than 4.5 square metres, with a minimum length of 3 metres and a minimum width of 1.5 metres;	Need to include in design.
	(c) not face each other or are more than 3 metres apart, have a verandah attached to the temporary accommodation building with a minimum floor area of 4.5 square metres, minimum length of 2.5 metres and a minimum width of 1.8 metres?	Need to include in design.
P11 **Weather**	*Are communal facilities connected to every sleeping compartment by a covered walkway which:*	
	(a) is not less than 1.5 metres wide;	Not applicable as the RTEHM is intended to be

Performance Criteria	Requirements	Comments Red = Requires action
protection		designed as a self contained unit that is not reliant on communal facilities.
	(b) has a concrete or bitumen surface;	Not applicable as the RTEHM is intended to be designed as a self contained unit that is not reliant on communal facilities.
	(c) is protected from the weather by an impervious roof covering?	Not applicable as the RTEHM is intended to be designed as a self contained unit that is not reliant on communal facilities.
	Facilities	
P12	*Does each sleeping compartment have an ensuite or communal facilities with:*	
Bathing and sanitary facilities	*(a) a double power point;*	Need to include in design.
	(b) hot and cold water outlets to each shower with a shower rose;	Need to include in design.
	(c) a vanity mirror, vanity shelf, towel rail, toilet roll holder and clothes hook;	Need to include in design.
	(d) a shower;	Need to include in design.
	(e) a dual flush water closet cistern and pan with a minimum floor area of 0.81 square metres;	Need to include in design.
	(f) one fixed wash basin with internal overflow relief facility and a water stop plug permanently attached to the basin;	Need to include in design.
	(g) if items (d), (e) or (f) are in separate cubicles, cubicle doors able to be latched closed from the inside and removable from the outside?	Not applicable as ensuite will be designed as an open module in itself.
	If communal facilities are provided are they:	
	(a) in a building which is less than 20 metres from the door of the occupied sleeping compartment or located in the same building as the sleeping compartment;	Not applicable as the RTEHM is intended to be designed as a self contained unit that is not reliant on communal facilities.

Performance Criteria	Requirements	Comments Red = Requires action
	(b) separated by walls extending from the floor to the ceiling between individual facilities?	Not applicable as the RTEHM is intended to be designed as a self contained unit that is not reliant on communal facilities.
P13 **Laundry**	*Are laundry facilities located less than 60 metres from a sleeping compartment?*	Need to include in design.
	Do the laundry facilities have:	
	(a) one automatic washing machine provided with each 8 beds or part thereof;	Need to include in design.
	(b) one fixed wash tub provided with hot and cold piped water with each 20 beds or part thereof;	Need to include in design.
	(c) one double power point for appliances;	Need to include in design.
	(d) clothes drying facilities comprising clothes line or hoist with 7.5 metres of line per bed or one 6.8 kilogram heat operated drying cabinet or appliance for every 8 beds?	Need to include in design.
P14 **Kitchen**	*If a communal kitchen is not provided or food is not catered for externally, is there a food preparation area with a:*	
	(a) double power point;	Need to include in design.
	(b) storage cupboard of at least 0.7 m^2?	Need to include in design.
P15 **Refrigeration facilities**	*Does each sleeping compartment have:*	
	(a) a 100 litre refrigerator;	Need to include in design.
	(b) access to a 500 litre refrigerator for each 20 beds or part thereof, within a 20 metre distance of each sleeping compartment?	Not applicable as the RTEHM is intended to be designed as a self contained unit that is not reliant on communal facilities.
P16 **Dining facilities**	*Are communal dining facilities provided and located less than 70 metres from sleeping compartments?*	Not applicable as the RTEHM is intended to be designed as a self contained unit that is not reliant on communal facilities.
P17 **Storage facilities**	*If the accommodation unit is for use by more than one resident, does each resident have a personal storage unit which is weatherproof,*	Need to include in design.

Performance Criteria	Requirements	Comments Red = Requires action
	lockable, at least 1.5 metres in height and at least 0.7 m^3 in volume?	
P18 Communications	*Do you have access to the internet and telephone where coverage is available?*	The scope for this design only includes the development of an emergency housing structure. Hence, communications are not applicable.
Sustainable Building Measures		
P19 Energy and water resources	*Has the temporary accommodation been fitted with:*	
	(a) energy efficient lighting complying with MP 4.1 of the QDC;	Need to include in design.
	(b) toilet cisterns complying with MP 4.1 of the QDC?	Need to include in design.
Requirements for Certain Short Term Temporary Accommodation Buildings		
P20 Duration of use	*Is the temporary accommodation building:*	
	(a) intended or approved to remain on site for periods of 42 days or less;	Not applicable as the RTEHM will be designed for longer durations to make the so that it can be used in more situations.
	(b) existing and *(i) in lawful use on the day this code commences;* *(ii) is moved to a new site only once within a two year period from the commencement of this code;* *(iii) intended or approved to remain on a site for periods of 112 days or less?*	Not applicable as the RTEHM is not an existing building.

Sources: (Department of Housing, 2014); (Department of Housing, 2021)

It can be seen that a vast majority of the requirements are not actually relevant to the design of the RTEHM due to different codes, communal facilities or simply being outside the scope of this project. Anything outside of the base structure and fit-out and materials will not be included in the design as these are deemed as external factors that will be assessed separately on site. A potential follow up to this project could be to determine the logistics of implementing this emergency housing model in a real life setting. This could include a case study where a site is selected and a large scale community is modelled similar to the Wollongbar village discussed earlier in this dissertation.

4.1.4 Base structure

The first step in the detailed design process is to define the base structure. Continuing on from the concept design, we know the physical dimensions of the tank to be as follows:

- Tank diameter – 3550 mm
- Tank height (cylinder) – 2235 mm
- Tank height (dome) – 2835 mm

With the external dimensions fixed, the internal layout needs to be designed. This involves determining the best configuration for the walls. Figure 41 below shows a variety of different base structure wall configurations ranging from 6 sides to 10 sides.

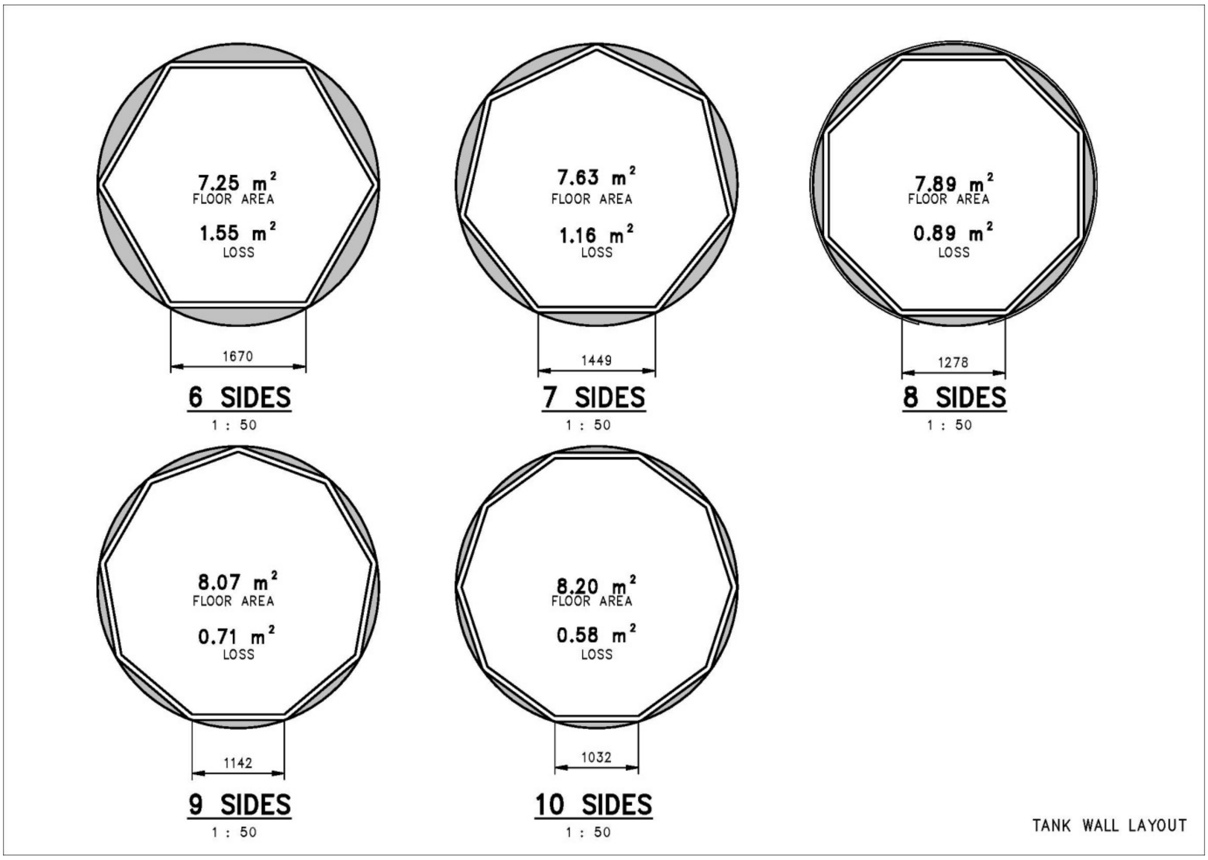

Figure 41 – Different base structure wall configurations

The purpose of trialling different wall configurations is to find a balance between preserving open floor space, reducing the wall materials and also assessing potential for modularisation. The only limiting factor in the design as per QDC MP 3.3 is that a minimum floor area of 5.6 m^2 is required for each bed. As such, any design will ensure that this requirement is satisfied.

The number of walls used for this assessment ranged from 6 sides to 10 sides. It was found that any number of walls less than 6 sacrificed too much open floor space whereas any number of walls greater than 10 only made negligible improvements to the amount of open floor space at the expense of increasing building costs.

It can be seen that the floor space lost for the 6 side configuration is approximately 1.55 m^2 whereas for the 10 side configuration the floor space lost is 0.58 m^2. Alternatively, the 8 side configuration has a reduced floor space of 0.89 m^2. Hence, there is not a linear relationship between the number of walls and the floor space lost, rather a logarithmic one where each added wall increases the floor area at a reduced rate to the previous one.

The other important consideration for the internal layout is the ability to modularise the design. For this to occur as envisioned, two adjacent modules will need to be orientated so that the face of one of their walls is parallel and aligned. The overlapping external sections of the tanks will be removed to provide an opening between the two. The two tanks will be sealed together by plastic welds or other industry acceptable practices. A door will be installed in one of the tank walls and a short hallway will be constructed to allow passage between the two.

With the above information in mind, it is important to note that the more walls in the module, the less of an overlap there will be between the tanks as the adjacent walls will be closer. This will in turn mean less production costs and more efficient use of the space available.

The last factor to take into account is the total space taken up by a RTEHM with multiple modules. The most ideal configuration to save space is one where the modules can connect at the quadrant points i.e. 90° intervals. With this layout, an infinite array of modules can be connected in the exact same way at the same locations. Not only does this keep the modules as close together by reducing the space between modules but it also simplifies the design and assembling processes. To achieve this, the wall configuration needs to have biaxial symmetry, meaning that each quadrant of the module needs to be a mirror opposite of the others. This only occurs in shapes with sides in multiples of 4. Referring back to Figure 41, it is visually apparent that only the 8 side configuration exhibits biaxial symmetry. Similarly, although not shown, a 12 side configuration would also demonstrate this behaviour as would a 16, 20, and 24 side configuration and so on.

Considering all of the above, it is clear to see that the 8 side configuration is the best overall design choice as it is able to meet all of the demands. Odd numbered wall configurations (7 & 9) offer poor modularisation, a 6 side configuration loses out on too much floor space and a 10 side configuration only gains an extra 0.31 m^2 of floor space over an 8 side configuration which isn't worth it for the added expense. Despite the fact that wall width decreases as the number of walls increases, the 8 side configuration still has a wall width of 1278 mm which is large enough to comfortably fit a standard 820 mm door or window. Lastly, it is still desirable to have somewhat of a void between the internal walls and the wall of the tank. These pockets are where the insulation is anticipated to go so the more space available, the more insulation that can be provided. In essence, the 8 side configuration is the best option and it will be used to create the base structure.

4.1.5 Fit-out and materials

Now that a base structure has been finalised and the floor area is determined, it is critical to provide all of the necessary requirements of Table 14 in a way that is compact and efficient.

To summarise, the following items and appliances are to be included in the design:

- Double power points
- Fibre cement, plasterboard or timber lined walls
- Air conditioning or flyscreens on doors and windows
- Shower
- Vanity mirror, vanity shelf, towel rail, toilet roll holder and clothes hook
- Toilet
- Wash basin (for both sanitary and laundry purposes)

- Washing machine
- Clothes dryer
- Storage cupboard
- Refrigerator
- Storage unit
- Lighting

In an ideal world, all of these items can be sourced directly from C&D waste materials in working condition. However, as is the case with most C&D waste materials, they are typically damaged and not suitable for reuse in their current form. Hence, it is important to assess other avenues of repurposing C&D waste materials to fulfil a role in emergency housing. Some of the materials discussed in Chapter 3 are again referenced below in Table 15.

Table 15 – Potential uses for available waste resources

Material	Purpose
Recycled timber	Framing, cladding, flooring
Crushed concrete	Foundation
Condensed polystyrene	Insulation
Aluminium cans	Insulation
White goods	Reuse
Electronics	Run appliances
Steel	Window frame

Now that we have a better idea as to what is needed and what is available for reuse, the next step is to put together a detailed design where the internal fit-out optimises the space available in the RTEHM. Figure 42 below shows a finalised kitchen layout plan where the relevant items and appliances are included and some extra quality of life additions also.

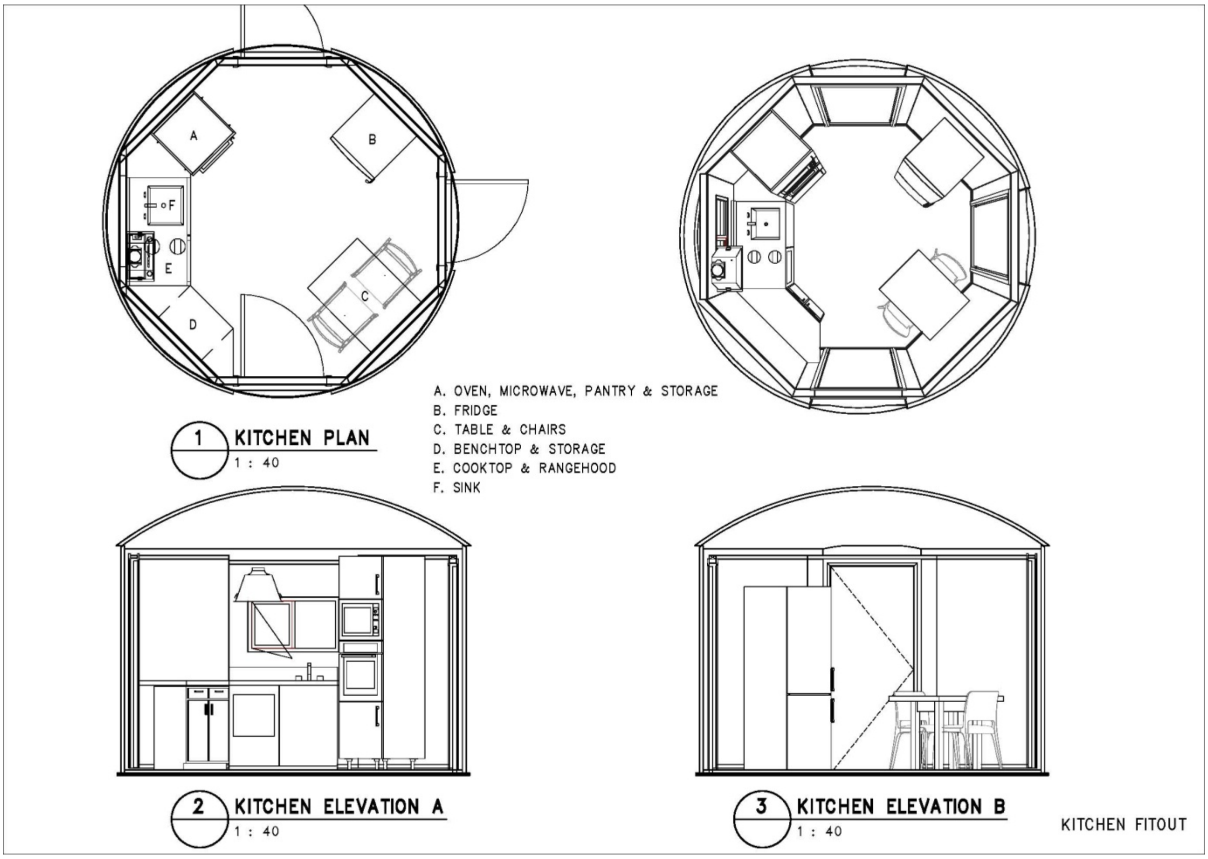

Figure 42 – Kitchen fit-out design drawings

The final result is a compact unit that provides all of the amenities in a spacious setting. The most important design factor in all of the modules was to ensure that at least 3 of the connecting sides were left unimpeded to allow for modularisation. For more design drawings of other modules and different layout configurations, see Appendix G – Design Drawings.

4.2 Logistics

The next step in the design phase is to determine the logistics of the build now that we have the footprint of the model finalised. This involves accounting for the quantity of materials used in the design and then associating an appropriate cost to said items. In total, all of the items, including labour, should add up to give us a final cost estimate for the model.

4.2.1 Schedule of materials

In order to determine the rate for a given item, it is first important to understand the unit each item is measured in. These standards are typically set by industry as they are often the easiest ways to quantify certain items. For example, timber is quoted by distance i.e. per linear metre but wall sheeting is quoted by its area i.e. per square metre. Hence, following standard industry practice where possible, the timber framing schedule was produced from the Revit model of the RTEHM.

Table 16 – Timber framing schedule

Family	Stud Width	Stud Length	Wall Stud Spacing	Unconnected Height	Length Internal Face	Length Centre Line	Area
	mm	mm	mm	mm	mm	mm	m^2
Basic Wall (1)	70	35	450	2100	1278	1307	3.10
Basic Wall (2)	70	35	450	2100	1278	1307	2.89
Basic Wall (3)	70	35	450	2100	1278	1307	2.89
Basic Wall (4)	70	35	450	2100	1278	1307	2.89
Basic Wall (5)	70	35	450	2100	1278	1307	2.89
Basic Wall (6)	70	35	450	2100	1278	1307	2.89
Basic Wall (7)	70	35	450	2100	1278	1307	2.89
Basic Wall (8)	70	35	450	2100	1278	1307	2.68
Total							**23.12**

cont.

Family	Bottom Plate	Top Plate	Nailing Plate	Stud Height	Stud Div	Stud Count	Nogging Length Per Wall Panel	Nogging Length Single	Insulation Volume
	mm	mm	mm	mm	m		mm	mm	m^3
Basic Wall (1)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Basic Wall (2)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Basic Wall (3)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Basic Wall (4)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Basic Wall (5)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869

Basic Wall (6)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Basic Wall (7)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Basic Wall (8)	2100	2100	2100	2030	2.84	4	1138	379.3	1.869
Total	**16800**	**16800**	**16800**	**16240**			**9104**		**14.952**

From this timber framing schedule, it is estimated that the amount of timber framing required will be 76 linear metres. Accounting for wastage, this can be approximated as 90 linear metres for each 8 side configuration RTEHM. Similarly, with wastage, it is estimated that each module will require approximately 30 m^2 of wall sheeting, 16 m^3 of insulation and 10 m^2 of flooring, respectively. This represents all of the items that have measureable quantities by physical proportions. The remaining items are singular and are simply measured by how many of them there are in the RTEHM.

4.2.2 Final cost analysis

Now that we have the schedule of materials for the measureable items, we can proceed to producing a schedule of rates where all of the items are combined and they have costs assigned to them. The final cost analysis is important as it is the last hurdle that the RTEHM has to clear to ensure that it has stayed true to the original aims and objectives set at the start of the project. Hence, it is important to make sure that the prices selected for the individual items are accurate and reflect the market otherwise it would be misleading stakeholders into thinking that the RTEHM is something that it is not. In saying that, however, it is not a simple task either to estimate the value of waste materials. The value can vary based on the condition of the materials and also who is selling them.

During research, it was difficult to obtain the cost of waste materials due to a number of factors. Firstly, there aren't a lot of publications that even discuss the specific costs of C&D waste materials when they are getting reused. Mostly, they just give an estimate of how much C&D waste is saved from landfill and give it an equivalent worth based on the amount of new materials that were not used as a result. This information is irrelevant for this project as we need to break each item down as its own entity to get an accurate cost estimate. Secondly, despite GTWMF being the focus of the initial case study for this project, it was discovered through discussions with them that they do not recycle for resale to the public. As a result, they were not able to disclose any information regarding the cost of distributing waste materials.

Hence, after much deliberation, it was decided that the best place to look for information about the cost of C&D waste materials was second hand retailers who predicate their business on knowing the market value of waste materials. As a result, a local second hand retailer called Raleigh Secondhand Barn was visited to inspect the variety of C&D waste materials and second hand items that they had available. Raleigh Secondhand Barn is a family owned and operated business that has been running for over 40 years in Raleigh, NSW. They collect large quantities of C&D waste materials from condemned sites and deceased estates. They also offer demolition services where they can come and retrieve doors, floorboards and other reusable materials. They have marketed their business around environmental sustainability and they believe in upcycling everything from furniture to raw building materials (Raleigh Secondhand Barn, n.d.).

Figure 43 – Reclaimed timber

Source: (Raleigh Secondhand Barn, n.d.)

Figure 44 – Retrieved doors and windows

Source: (Raleigh Secondhand Barn, n.d.)

Discussions with a representative from Raleigh Secondhand Barn revealed that many local residents purchase the reclaimed waste materials and some builders have also purchased second hand building resources from them at the request of their clients. Hence, they are clearly experienced as distributors in the market for C&D waste materials.

For the purpose of this project, they were happy to have discussions pertaining to the cost of the items in the RTEHM and provide insight into the rates for particular items, even if they weren't items that they had regularly at their warehouse. As a result, the rates for most of the items below in Table 17 are provided in accordance with those stipulated by Raleigh Secondhand Barn.

Table 17 – Schedule of rates

Item	**Unit**	**Quantity**	**Rate**	**Cost**
All modules				
Rainwater tank	Each	1	$3195.00	$3195.00
70 x 35 pine timber	m	90	$5.50	$495.00
Bracing plywood	m^2	30	$13.00	$390.00
Insulation (polystyrene / cans)	m^3	16	-	-
Window	Each	1	$160.00	$160.00
Ceiling light	Each	1	$10.00	$10.00
Double power point	Each	1	$10.00	$10.00
Timber door	Each	1	$120.00	$120.00
Total				**$4380.00**
Kitchen module				
Storage cupboard	Each	1	$120.00	$120.00
Refrigerator	Each	1	$150.00	$150.00
Timber flooring	m^2	10	$45.00	$450.00
Microwave	Each	1	$50.00	$50.00
Table	Each	1	$100.00	$100.00
Chairs	Each	2	$25.00	$50.00
Benchtop with sink	Each	1	$150.00	$150.00
Total				**$1070.00**
Bathroom / laundry module				
Fibreglass shower	Each	1	$250.00	$250.00
Vanity mirror	Each	1	$20.00	$20.00
Vanity shelf	Each	1	$50.00	$50.00
Towel rail	Each	1	$20.00	$20.00
Toilet roll holder	Each	1	$5.00	$5.00

Clothes hook	Each	4	$5.00	$20.00
Toilet	Each	1	$50.00	$50.00
Wash basin with storage	Each	1	$150.00	$150.00
Washing machine	Each	1	$150.00	$150.00
Clothes dryer	Each	1	$150.00	$150.00
Tile flooring	m^2	10	$21.00	$210.00
Total				**$1075.00**
Bedroom module				
Lockable storage unit	Each	1	$120.00	$120.00
Timber flooring	m^2	10	$45.00	$450.00
Bed	Each	1	$250.00	$250.00
Bedside table	Each	2	$50.00	$100.00
Total				**$920.00**
Verandah				
Concrete pavers	m^2	4.5	$20.00	$90.00
Metal roofing	m^2	4.5	$30.00	$135.00
Total				**$225.00**

Source: (Raleigh Secondhand Barn, 2024)

Note: Some quality of life items have been added on top of the basic requirements. These are shown in *italics*.

Some of the minor items such as the bathroom accessories are not typical items that they stock as most people would buy those items brand new but for the purpose of this project they are assumed to be waste materials so the rate is set at a cost less than recommended retail price.

Table 18 – Total material cost per module

Module	**Total cost (excluding cost of rainwater tank)**	**Total cost (including cost of rainwater tank)**
Kitchen	$2255.00	$5450.00
Bathroom / laundry	$2260.00	$5455.00
Bedroom	$2105.00	$5300.00
Verandah	$225.00	$225.00

The total material cost per module is calculated by adding the total cost of a standard module with the total cost of the item that reflects its function. Each module has a foundational cost of $4380 but then the added costs depend on what type of module it is. For example, the items that are specific to a kitchen module have a total cost of $1070 so the total cost for a kitchen module is $5450.

Although this project was initially proposed to be built from gifted tanks, the costs of the tanks are also included as they were not seen to be a sustainable source for building emergency housing. It also keeps the cost analysis honest and more realistic when comparing the RTEHM to other forms of emergency housing.

Table 19 – Total labour cost per module

Module	**Number of tradesmen**	**Estimated hours to construct**	**Rate per tradesman**	**Cost**
Kitchen	3	4	$100.00	$1200.00
Bathroom / laundry	3	4	$100.00	$1200.00
Bedroom	2	3	$100.00	$600.00
Verandah	2	3	$100.00	$600.00

Table 19 above shows the rationale behind determining the cost of labour to construct each module. It is based on a team of 2-3 tradesmen and estimates how many hours it will take the crew of workers to complete the module. The rate is set at $100 per hour which is an estimation based on the Rawlinsons Construction Guide 2021. In the guide, it estimates that in Brisbane, a tradesman will cost approximately $62-$74 per hour for wages. The guide also provides a list of plant hire rates and their usual costs per day. Assuming the tradesmen will use their own tools and equipment or even if they do intend to hire it, an allowance has been made to accommodate for these costs also. Hence, the rate of $100 per hour is an all inclusive rate that incorporates the labour from the workers and the equipment that they need to use. For more information on the Rawlinsons cost guide relating to labour costs, see Appendix F – Rawlinsons Wage & Plant Hire Rates.

Table 20 – Total cost per configuration

Number of modules	Allocation of modules	Material cost	Labour cost	Total cost
1	1 x bedroom	$5300	$600	**$5900**
	1 x verandah	$225	$600	**$825**
Total		**$5525**	**$1200**	**$6725**
2	1 x bedroom	$5300	$600	**$5900**
	1 x bathroom / laundry	$5455	$1200	**$6655**
	1 x verandah	$225	$600	**$825**
Total		**$10,980**	**$2400**	**$13,380**
3	1 x bedroom	$5300	$600	**$5900**
	1 x bathroom / laundry	$5455	$1200	**$6655**
	1 x kitchen	$5450	$1200	**$6650**
	1 x verandah	$225	$600	**$825**
Total		**$16,430**	**$3600**	**$20,030**
4	2 x bedroom	$10,600	$1200	**$11,800**
	1 x bathroom / laundry	$5455	$1200	**$6655**
	1 x kitchen	$5450	$1200	**$6650**
	2 x verandah	$450	$1200	**$1650**
Total		**$21,955**	**$4800**	**$26,755**

Combining the material costs and the labour costs we are able to get a total cost per configuration. As can be seen in Table 20, the total cost for a configuration with 4 modules is $26,755. This satisfies the original target for this project which was to design an emergency housing model for under $30,000.

Table 21 – Cost comparison between existing and design temporary housing models

Temporary housing model	Cost
Prefabricated modular tiny homes (Boxabl)	$80,000
Mobile tiny homes (VanHomes)	$88,320
Mobile tiny homes (Aussie Tiny Houses)	$96,900
Pods (Minderoo / Hutchinson)	$30,000
RTEHM – 4 modules (concept design)	$78,155

RTEHM – 4 modules (detailed design)	$26,755

Comparing the RTEHM to the other temporary housing models on the market shows that it is competitive financially and is a cost effective alternative. From a cost standpoint, it is on a similar level to the pods but it offers the features and functionality of a more expensive option such as the prefabricated modular tiny homes.

Another interesting comparison for the RTEHM is looking at the cost estimation differences between concept and detailed design stages of the project. The initial cost estimation at the concept design stage was based on Rawlinsons guidelines which are not intended for emergency housing. The fit-out items are more reflective of a higher quality product to be used in a commercial setting. As a result, the cost is overestimated for the scope of this project. This can be seen by the dramatic drop off in cost between the concept and detailed design stages where the cost goes from $78,155 to $26,755 – a 66% decrease. Another factor that obviously plays a part in the cost difference is that the concept design doesn't take into account the use of C&D waste materials to construct the RTEHM. Using second hand materials is going to reduce the costs significantly and this is evident in the price difference.

4.2.3 Transportation logistics and assembly requirements

Now that the cost analysis is finalised, the next step is to determine the best way to transport the RTEHM. The benefit of the RTEHM is that it is a self contained unit that can be assembled prior to transportation or on site – whatever is required in a particular situation. For the purpose of this study, it has been decided that the latter option of assembling the units on site is the better choice as the components can be individually transported to site and the chance of them being damaged during transportation can be managed more effectively.

Figure 45 – Tanks being transported by trucks

Source: (The Water Tank Factory, n.d.)

The rainwater tanks themselves already have a standard method of transportation as can be seen in Figure 45. Tanks can be easily loaded onto the back of trucks and driven to the desired location. The main advantage of this is that the tanks can be transported anywhere a truck can travel. Once they have arrived on site, they can easily be manipulated by a small group of people and rolled to their final resting space. For most general applications, a crane will not be needed to install the RTEHM in place, only if it is to be lifted up off the ground on piles or something similar.

On the other hand, if the RTEHM units were to be fully furnished prior to transportation to site, this manual handling of the units would not be possible as they would be too heavy and the internal fixtures would almost surely get damaged. This means that the only form of getting the units into place is by using a crane which makes the process a lot more expensive and time consuming.

Once the RTEHM units have been rolled into place, the tradesmen can then begin their work of installing the internal fixtures and cutting out the entryways in the side of the tanks. One of the ways the workflow can be streamlined is to have the wall panels prefabricated and transported to site on the back of a truck. This way the panels just need to be carried from the truck and straight into the RTEHM to be installed. This would eliminate a significant step in the construction of the modules and decrease turnaround time. It would also mean that a number of modules could be quickly set up in succession and then the fit-out stages could come at a later date or be staggered to suit time frames.

Figure 46 – Prefabricated wall panels being transported via semi-trailer
Source: (Worldwide Truss and Frames, n.d.)

It is estimated that it will take a team of 2-3 tradesmen approximately 14 hours to fully construct a 4 module RTEHM. Extrapolating this out, it is expected that five of the 4 module RTEHM units can be installed in a standard working week. Obviously if the number of workers were to increase, so would the output of RTEHM units being installed. Hence, the timeframes involved in installing the RTEHM units can be varied by either increasing the amount of tradesmen or stretching out the design installation period. However, these timeframes are simply design assumptions that have been made in order to determine a cost estimate for the labour. The actual timeframes may vary significantly when it comes to constructing the units in a real-life setting.

4.3 Design renders

At this point in the design stage, there is enough information to design and construct the RTEHM. However, until this actually occurs, the concept is not yet finalised. Hence, being able to visualise the completed model is an important step in gaining perspective on how things fit together and understanding how to best manage any issues that may become apparent.

One of the ways to create a visual representation of the model is to use a 3D visualisation tool such as Twinmotion. Being immersive software, it is able to take wireframes of buildings and architectural features from programs such as AutoCAD and Revit and convert them into renders which can have materials and textures applied to them. There are a number of other tools offered in the software such as being able to place people and objects in and around imported buildings as well as change environmental factors such as the position of the sun, weather and time of day (Twinmotion, n.d.).

For these reasons, Twinmotion was selected to create design renders for the RTEHM. The process of importing the design from Revit into Twinmotion was straightforward. A design surface was also brought across from AutoCAD which included a ring road and designated parking spaces for each RTEHM site so as to make a community or village. Once in Twinmotion, appropriate materials and textures were applied and the relevant items were included in the fit-out of the RTEHM. Figure 47 below is an excerpt from Twinmotion and effectively illustrates the design of the RTEHM in a real life setting and how it would look if it were to be implemented. For more design renders, see Appendix H – Design Renders.

Figure 47 – Rendered view of RTEHM village

Chapter 5 – Conclusion

This research project aimed to explore the design of emergency housing from C&D waste materials. By understanding the need for emergency housing and some of its uses, the themes of simplicity, ease of setup and affordability were at the forefront of all design discussions. In line with these themes was the desire to construct the emergency housing from as many C&D waste materials as possible so as to not only reduce costs but also facilitate sustainability by reusing waste materials that would otherwise go to landfill. As a result, the idea for the RTEHM was born and this project followed its development from concept stages to fully detailed designs as well as feasibility assessments and cost analyses.

The final build was centred on a modular design that allowed for flexible living arrangements to suit the needs of individuals or families alike. The design needed to comply with temporary accommodation building guidelines as stipulated by Queensland development codes. Putting all of this into action, the largest unit designed for the RTEHM was a 4 module configuration which was estimated to cost approximately $27,000 inclusive of materials and labour. This compares favourably to other existing temporary housing products on the market which either had significantly higher costs or offered a smaller package with less features.

This project has a number of implications for the development of emergency housing. Most importantly, this project proved that it is affordable and realistic to construct a form of emergency housing by utilising C&D waste materials to supplement its design. Additionally, this project can act as a blueprint for any emergency housing projects in the future that may incorporate the ideas presented. Lastly, the decision to reuse waste materials is another step in the right direction to achieve the end goal of a circular economy where all waste items have a renewed value in another setting.

Despite the relative success of this project, there are a few areas of concern that are worth discerning. The most obvious one is the fact that not all waste materials are equal and their condition can vary significantly. This introduces a grey area into the decision making for emergency housing that is reliant on reusing waste materials. The last thing you would want is to build emergency housing that fails because a section of the build was constructed with defective materials. As a result, mandatory wellbeing assessments on the integrity of structural elements should be implemented to ensure that the waste materials are checked by professionals who can verify them as being safe and suitable for reuse.

Another issue encountered in this project was how difficult it was to acquire the cost rate for waste materials. Second hand items do not inherently have a set rate as their value varies dependent on their condition. This sentiment is further supported by the lack of costing information in literature. At best, there were rough cost estimates for the sorting and processing of raw waste materials but nothing to determine a cost rate against a quantity. Even GTWMF wasn't able to provide information about the cost of second hand waste materials as that is out of their jurisdiction. As a result, the only way we were able to obtain cost data was to inquire at third party waste recyclers. Given that waste recyclers operate under independent business models as opposed to government agencies such as GTWMF, it can be expected that there would be a decent amount of variance in the cost of waste materials between recyclers. Hence, it would be beneficial to have a study that collects data on the value of second hand waste items and materials. This information could then form a database founded by literature which would more adeptly represent the value of waste materials. This would ensure a more accurate cost analysis for future emergency housing projects and instil a level of consistency across projects.

As far as future work regarding this project is concerned, the next step in the design would naturally be to build a RTEHM in a controlled environment. This would enable us to gain a real-life insight into the logistics of the design such as the exact amount of materials used and man hours spent to build it. Beyond this, the case study could be expanded to other local government authorities with the design being adapted to suit the new regulations.

List of References

Aussie Tiny Houses. (n.d.). *Aussie Tiny Houses - Tiny Houses in Australia for Sale* [Online]. Available at: https://aussietinyhouses.com.au/ [Accessed 11/05/2023].

Aussie Tiny Houses. (n.d.). - *Tiny Houses Photo Gallery* [Online]. Available at: https://aussietinyhouses.com.au/gallery/ [Accessed 11/05/2023].

Australian Bureau of Statistics (2020). *Waste Account, Australia, Experimental Estimates, 2016-17 | Australian Bureau of Statistics* [Online]. Available at: https://www.abs.gov.au/statistics/environment/environmental-management/waste-account-australia-experimental-estimates/latest-release [Accessed 30/08/2023].

Australian Bureau of Statistics. (2023). *Estimating Homelessness: Census* [Online]. Australian Bureau of Statistics. Available at: https://www.abs.gov.au/statistics/people/housing/estimating-homelessness-census/latest-release#:~:text=Of%20the%20122%2C494%20people%20experiencing. [Accessed 19/08/2023].

Australian Government. (2011). *Construction and demolition waste guide – recycling and re-use across the supply chain* [Online]. Department of Sustainability, Environment, Water, Population and Communities. Available at: https://www.dcceew.gov.au/sites/default/files/documents/case-studies.pdf [Accessed 20/05/2023].

Australian Government. (n.d.). *Bushfires – Black Summer* [Online]. Australian Institute for Disaster Resilience. Available at: https://knowledge.aidr.org.au/resources/black-summer-bushfires-vic-2019-20/ [Accessed 12/08/2023].

Australian Government. (n.d.). *COVID-19 and travel* [Online]. Department of Health and Aged Care. Available at: https://www.health.gov.au/topics/covid-19/travel [Accessed 19/08/2023].

Australian Government. (n.d.). *Natural hazards and climate change* [Online]. Australian Institute for Disaster Resilience. Available at: https://knowledge.aidr.org.au/resources/natural-hazards-and-climate-change/ [Accessed 19/08/2023].

Autodesk. (n.d.). *Autodesk AutoCAD: Trusted by millions, built to accelerate your creativity* [Online]. Available at:

https://www.autodesk.com.au/products/autocad/overview?mktvar002=5019031 [Accessed 11/06/2023].

Autodesk. (n.d.). *Autodesk Revit: BIM software to design and make anything* [Online]. Available at: https://www.autodesk.com.au/products/revit/overview?term=1-YEAR&tab=subscription [Accessed 18/01/2024].

Autodesk. (n.d.). *Company* [Online]. Available at: https://www.autodesk.com.au/company [Accessed 11/06/2023].

Boxabl. (2021). *Boxabl News – Boxabl's Patented Shipping and Packing Technology to Transform Construction Sector* [Online]. Available at: https://www.boxabl.com/boxabls-patented-shipping-and-packing-technology-to-transform-construction-sector/ https://www.boxabl.com/plans [Accessed 27/08/2023].

Boxabl. (2021). *Boxabl News – Construction Startup Takes Housing to the Assembly Line* [Online]. Available at: https://www.boxabl.com/construction-startup-takes-housing-to-the-assembly-line/ https://www.boxabl.com/plans [Accessed 27/08/2023].

Boxabl. (n.d.). *Boxabl – Accessory Dwelling Unit* [Online]. Available at: https://www.boxabl.com/ [Accessed 11/05/2023].

Boxabl. (n.d.). *Boxabl – Casita Foundations* [Online]. Available at: https://ha.boxabl.com/plans https://www.boxabl.com/plans [Accessed 26/08/2023].

Boxabl. (n.d.). *Frequently Asked Questions* [Online]. Available at: https://www.boxabl.com/faqs/ https://www.boxabl.com/plans [Accessed 27/08/2023].

Brogden, T. (2022). *Support Lismore's flood recovery* [Online]. Community Gateway. Available at: https://nrcg.org.au/support-lismore-flood-recovery/ [Accessed 11/05/2023].

Built Offsite. (n.d.). *Mass production of prefabricated housing on track for delivery* [Online]. Available at: https://builtoffsite.com.au/news/boxabl-prefabricated-housing/ [Accessed 11/05/2023].

Cho, Y. (2021). Chapter 8. Introduction to Revit. *iastate.pressbooks.pub*. [Online]. Available at: https://iastate.pressbooks.pub/visualgraphiccomm/chapter/chapter-8-introduction-to-revit/ [Accessed 18/01/2024].

Corder, B. (2015). *Asked & Answered: What is the expected lifetime of the expanded polystyrene (EPS) foam?* [Online]. BuildBlock Insulating Concrete Forms. Available at: https://buildblock.com/asked-answered-what-is-the-expected-lifetime-of-the-expanded-polystyrene-eps-foam/ [Accessed 09/09/2023].

CSIRO. (n.d.). *Circular Economy – About* [Online]. Available at: https://research.csiro.au/circulareconomy/about/ [Accessed 26/08/2023].

Department of Housing. (2014). *Temporary accommodation buildings and structures* [Online] Available at: https://www.epw.qld.gov.au/__data/assets/pdf_file/0014/4811/qdcmp3.3temporaryaccommodationbuildingsandstructures.pdf [Accessed 22/02/2024].

Department of Housing. (2021). *Form 24: Temporary accommodation buildings checklist* [Online] Available at: https://www.epw.qld.gov.au/__data/assets/pdf_file/0013/4072/form24temporaryaccommodationbuildingschecklist.pdf [Accessed 22/02/2024].

Dufty-Jones, R. (2017). A historical geography of housing crisis in Australia. *Australian Geographer*, 49(1), pp.5–23. DOI: https://doi.org/10.1080/00049182.2017.1336968.

Gilmore, H. 2022. *Anatomy of the Lismore disaster* [Online]. The Sydney Morning Herald. Available at: https://www.smh.com.au/interactive/2022/lismore-flooding/ [Accessed 04/04/2023].

Hutchinson Builders. (n.d.). *Lismore Temporary Housing* [Online]. Available at: https://www.hutchinsonbuilders.com.au/projects/residential/lismore-temporary-housing [Accessed 14/05/2023].

Jeffrey, C., 2011. Construction and demolition waste recycling: A literature review. *Dalhousie University's Office of Sustainability*, *35*.

Kabirifar, K., Mojtahedi, M. and Wang, C.C., 2021. A systematic review of construction and demolition waste management in Australia: Current practices and challenges. *Recycling*, 6(2), p.34.

Kurmelovs, R. 2021. *'Eye-watering': climate change disasters will cost Australia billions each year, study finds* [Online]. The Guardian. Available at: https://www.theguardian.com/environment/2021/oct/06/eye-watering-climate-change-disasters-will-cost-australia-billions-each-year-study-finds [Accessed 19/08/2023].

Metro Steel Windows & Doors. (2022). *How Long Do Steel Windows Last? The Truth About Steel Windows* [Online]. Available at: https://www.metrosteeldoors.com/how-long-do-steel-windows-last-the-truth-about-steel-windows/ [Accessed 09/09/2023].

Minderoo Foundation. (2020). *Bushfire victims to benefit from ramp up in recovery pods for NSW* [Online]. Available at: https://www.minderoo.org/fire-and-flood-resilience/news/bushfire-victims-to-benefit-from-ramp-up-in-recovery-pods-for-nsw/ [Accessed 14/05/2023].

Minderoo Foundation. (n.d.). *Minderoo Foundation Recovery Pods* [Online]. Fact Sheet Available at: https://cdn.minderoo.org/content/uploads/2020/03/10112920/MF-FF_Recovery-Pod_Fact_Sheet_200409.pdf [Accessed 29/08/2023].

Minderoo Foundation. (n.d.). *Temporary Accommodation Pods | Fire and Flood Resilience | The Minderoo Foundation* [Online]. Available at: https://www.minderoo.org/fire-and-flood-resilience/resilient-communities/resources/temporary-accommodation-pods/ [Accessed 14/05/2023].

Ministry for the Environment. (2007). *6 Costs of Recycling* [Online]. New Zealand Government. Available at: https://environment.govt.nz/publications/recycling-cost-benefit-analysis/6-costs-of-recycling/ [Accessed 04/09/2023].

Morris, M. (2015). *Black Saturday rebuilding led to 'underutilised' infrastructure that pushed rates higher, residents say* [Online]. ABC News. Available at: https://www.abc.net.au/news/2015-01-12/black-saturday-infrastructure-marysville-cautionary-tale-sa-fire/6013114 [Accessed 12/08/2023].

National Museum Australia. (2023). *Black Saturday bushfires* [Online]. Available at: https://www.nma.gov.au/defining-moments/resources/black-saturday-bushfires [Accessed 12/08/2023].

NCC. (2022). *Understanding the NCC Building classifications* [Online] Available at: https://www.abcb.gov.au/sites/default/files/resources/2022/UTNCC-Building-classifications.PDF [Accessed 24/02/2024].

NSW Government. (2023). *Wollongbar Sports Field temporary housing village* [Online]. NSW Government. Available at: https://www.nsw.gov.au/floods/recovery/temporary-housing-programs/northern-rivers/wollongbar-temporary-housing [Accessed 14/05/2023].

Pickin, R., 2009. *Australian landfill capacities into the future* [Online]. Hyder Consulting. Department of the Environment, Water, Heritage and the Arts. Available at: https://www.dcceew.gov.au/sites/default/files/documents/landfill-capacities.pdf [Accessed 26/08/2023].

Queensland Government. (n.d.). *Temporary accommodation buildings and structures code* [Online] www.business.qld.gov.au. Available at: https://www.business.qld.gov.au/industries/building-property-development/building-construction/laws-codes-standards/queensland-development-code/temporary-accommodation#:~:text=Under%20MP%203.3%2C%20temporary%20accommodation [Accessed 22/02/2024].

QTimber. (2017). *Target design life* [Online]. Queensland Government. Available at: https://qtimber.daf.qld.gov.au/guides/target-design-life [Accessed 09/09/2023].

Raleigh Secondhand Barn. (n.d.). *Recycled Building Material in Raleigh | Raleigh Secondhand Barn* [Online]. Available at: https://www.raleighsecondhandbarn.com.au/recycled-building-material [Accessed 19/03/2024].

Rawlinsons Construction Cost Guide. 2021. Edition 29. Perth, Western Australia: Rawlinsons Publishing.

Rawlinsons Cost Management. (n.d.). Home webpage [Online]. Available at: https://www.rawlhouse.com.au/ [Accessed 04/09/2023].

Ridley, R. (2023). *How much waste does Australia generate and where does it go?* [Online]. Planet Ark. Available at: https://planetark.org/newsroom/news/how-much-waste-does-australia-generate-and-where-does-it-go#:~:text=In%202020%2D21%2C%20Australia%20generated [Accessed 26/08/2023].

Shooshtarian, S., Maqsood, T., Wong, P.S., Khalfan, M. and Yang, R.J., 2020. Market development for construction and demolition waste stream in Australia. *J. Constr. Eng. Manag. Innov*, *3*, pp.220-231.

Tankworld. (2023). *What is the lifespan of a poly water tank? - Tankworld Australia*. [Online]. Available at: https://www.tankworld.com.au/what-is-the-lifespan-of-a-poly-water-tank/#:~:text=A%20poly%20water%20tank%20can [Accessed 09/09/2023].

The Water Tank Factory. (n.d.). *Duraplas Tanks – built tough!* [Online]. Available at: https://www.watertankfactory.com.au/water-tank-photo-gallery/crane-lifting-water-tank-large/ [Accessed 07/09/2023].

The Water Tank Factory. (n.d.). *Water Tanks Brisbane QLD | Browse Our Huge Rainwater Tank Range* [Online]. Available at: https://www.watertankfactory.com.au/water-tanks-brisbane-qld/ [Accessed 02/03/2024].

Twinmotion. (n.d.). *Twinmotion is a Cutting Edge Real-Time Architectural Visualization Tool* [Online]. Available at: https://www.twinmotion.com/en-US [Accessed 19/03/2024].

VanHomes. (n.d.). *Discover the VanHomes Range Photo Gallery* [Online]. Available at: https://www.vanhomes.com.au/gallery [Accessed 11/05/2023].

VanHomes. (n.d.). *VanHomes Pricing Guide* [Online]. Available at: https://www.vanhomes.com.au/pricing-guide [Accessed 29/08/2023].

VanHomes. (n.d.). *VanHomes – Granny Flats Australia* [Online]. Available at: https://www.vanhomes.com.au/ [Accessed 11/05/2023].

Vasarhelyi, K. (2021). *The Hidden Damage of Landfills* [Online]. Environmental Center. Available at: https://www.colorado.edu/ecenter/2021/04/15/hidden-damage-landfills. [Accessed 26/08/2023]

Walker, C., 2022. *Climate Change and Natural Disasters* [Online]. Friends of the Earth Australia. Available at: https://www.foe.org.au/climate_change_and_natural_disasters [Accessed 19/08/2023].

Williams, J., Gilbert, G., Dawson, A., Kaldor, J., Hendrickx, D. and Haire, B. (2022). Uncertainty and agency in COVID-19 hotel quarantine in Australia. *SSM - Qualitative Research in Health*, 2, p.100034. DOI: https://doi.org/10.1016/j.ssmqr.2021.100034.

Worldwide Truss and Frames. (n.d.). *Timber Wall Frames* [Online]. Available at: https://worldwidetruss.com.au/wall-frames/ [Accessed 02/03/2024].

Zhao, X., Webber, R., Kalutara, P., Browne, W. and Pienaar, J., 2022. Construction and demolition waste management in Australia: A mini-review. *Waste Management & Research*, *40*(1), pp.34-46.

Zhu, P., Hao, Y., Liu, H., Wang, X., Liu, S. and Gu, L. (2019). Durability evaluation of three generations of 100% repeatedly recycled coarse aggregate concrete. 210, pp.442–450. DOI: https://doi.org/10.1016/j.conbuildmat.2019.03.203.

Appendix A – Project Specification

ENG4111/4112 Research Project
Project Specification

For: Liam O'Connor

Title: *Design of emergency housing from construction and demolition (C&D) waste materials*

Major: Civil Engineering

Supervisor: Dr. Hannah Seligmann

Enrollment: ENG4111 – EXT S1, 2023
ENG4112 – EXT S2, 2023

Project Aims: To investigate the viability of emergency housing built from C&D waste materials. A variety of appropriate materials are to be identified and analysed systematically based on design factors, production capabilities and economical benefits. The outcome of this project will be a concept level design of a transportable, modular emergency housing unit using C&D waste materials from the Greater Toowoomba Waste Management Facility (GTWMF)

Programme: Version 2, 14th March 2023

1. Conduct research for background information regarding the design of emergency housing using C&D waste materials.
2. Review current guidelines in QLD for temporary housing structures. This review can also be expanded to NSW for a broader scope if permissible.
3. Seek out potential C&D waste streams, preferably the Greater Toowoomba Waste Management Facility (GTWMF).

4. Attend GTWMF or other(s) to obtain an understanding of how waste materials are collected, stored and processed.
5. Develop an inventory management process flow chart and identify C&D waste materials that are being underutilised.
6. Determine processing requirements of C&D waste materials prior to use in emergency housing
7. Prepare a concept level design of a transportable, modular emergency housing setup using C&D waste materials.
8. Prepare manufacturing / assembly drawings and video
9. Prepare a high level cost estimate
10. Analyse and compare the concepts based on design factors, production capabilities and economical benefits.
11. Determine the most feasible design and comment on its viability.
12. Propose a recommendation of the selected design if suitable or provide insight as to why it is not.

If time and resource permits:

13. Expand scope of project to NSW or even national wide to ensure the emergency housing design concepts are acceptable outside of QLD.
14. Attend C&D waste streams in other LGA's to see if it is possible to replicate the results on a local scale. For me, this would most likely be in the Coffs Harbour region.

Appendix B – Risk Management Plan

2150	RISK DESCRIPTION	TREND	CURRENT	RESIDUAL
	ENG4111/4112 Research Project		Low	Low

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Liam O'Connor	15/03/2023	15/03/2023	15/03/2024

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Site visit to GTWMF. Walked all over the facility with Norm and took photos along the way. Had to be aware of customers driving in and out as well as any machinery that was operating. Had to be careful walking across uneven ground and avoid obstacles in the form of scattered waste.	Control: Had to wear the following: Steel capped work boots for foot protection Trousers for abrasion protection Hi-vis vest for visibility Hat for UV protection	Low	No Control:			Low
Sitting down at a desk to work on the research project on a computer at home or work	Control: Not considered currently for everyday use	Very Low	Sit with upright posture to reduce back pain and also sit at an appropriate distance from the monitor to reduce eye strain		11/09/2023	Very Low
Working at computer during the day or late at night	Control: Not considered currently for everyday use	Very Low	Working in intervals and taking regular breaks to prevent fatigue and migraines. Controlling room brightness and monitor brightness to suit conditions.		11/09/2023	Very Low

ATTACHMENTS
University of Southern Queensland Mail - USQ Civil Engineering Final Year Project.pdf

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Risk Assessment [Ref Number: 2150]

Date Printed: Wednesday, 15 March 2023

		Current Rating	Residual Rating
Name	**ENG4111/4112 Research Project**	Low	Low
Location	**Off Campus: Greater Toowoomba Waste Management Facility (GTWMF)**		

Business Unit	Last Review Date	Risk Owner
USQ Council	15/03/2023	Liam O'Connor

Risk Assessment Team	Risk Approver
Liam O'Connor	Hannah Seligmann

Additional Notes

A site visit was arranged via phone call. Risk management was discussed over the phone and appropriate personal protective equipment was worn to site.

Describe task / use

Project: Design of emergency housing using construction and demolition (C&D) waste materials

The project is being conducted in fulfillment of the requirements of ENG4111/4112

Risk Factors

Risk Factor	Fieldwork, Domestic and International Travel

Description	
Site visit to GTWMF. Walked all over the facility with Norm and took photos along the way. Had to be aware of customers driving in and out as well as any machinery that was operating. Had to be careful walking across uneven ground and avoid obstacles in the form of scattered waste.	• Does the fieldwork activity or travel need to take into consideration:

Risk Assessment [Ref Number: 2150]

Date Printed: Wednesday, 15 March 2023

Low	Low		
Existing Controls	**Proposed Controls**		
	Description	Responsibility	Target Date
• 6 - PPE: Had to wear the following: Steel capped work boots for foot protection Trousers for abrasion protection Hi-vis vest for visibility Hat for UV protection	**No Control:**		

Risk Factor	Ergonomics and Manual Handling

Description	
Sitting down at a desk to work on the research project on a computer at home or work	• Does the activity involve manual tasks: -- No • Does the work involve: • Does the work involve sustaining static postures for long periods of time e.g. sitting or standing? -- Yes • Are there egonomic hazards related to: • Furniture e.g. desks, chairs? -- Yes • Work station or work area design? -- Yes

Risk Assessment [Ref Number: 2150]

Date Printed: Wednesday, 15 March 2023

Very Low	Very Low		
Existing Controls	**Proposed Controls**		
• No existing controls required: Not considered currently for everyday use	Description	Responsibility	Target Date
	Sit with upright posture to reduce back pain and also sit at an appropriate distance from the monitor to reduce eye strain		11/09/2023

Risk Factor	Lighting

Description	
Working at computer during the day or late at night	• Is there the potential for: • Glare? -- Yes • High level lighting e.g. too bright? -- Yes • Low level lighting? -- Yes • Reflection? -- Yes

Very Low	Very Low		
Existing Controls	**Proposed Controls**		
• No existing controls required: Not considered currently for everyday use	Description	Responsibility	Target Date
	Working in intervals and taking regular breaks to prevent fatigue and migraines. Controlling room brightness and monitor brightness to suit conditions.		11/09/2023

Appendix

Documents Referenced
University of Southern Queensland Mail - USQ Civil Engineering Final Year Project.pdf

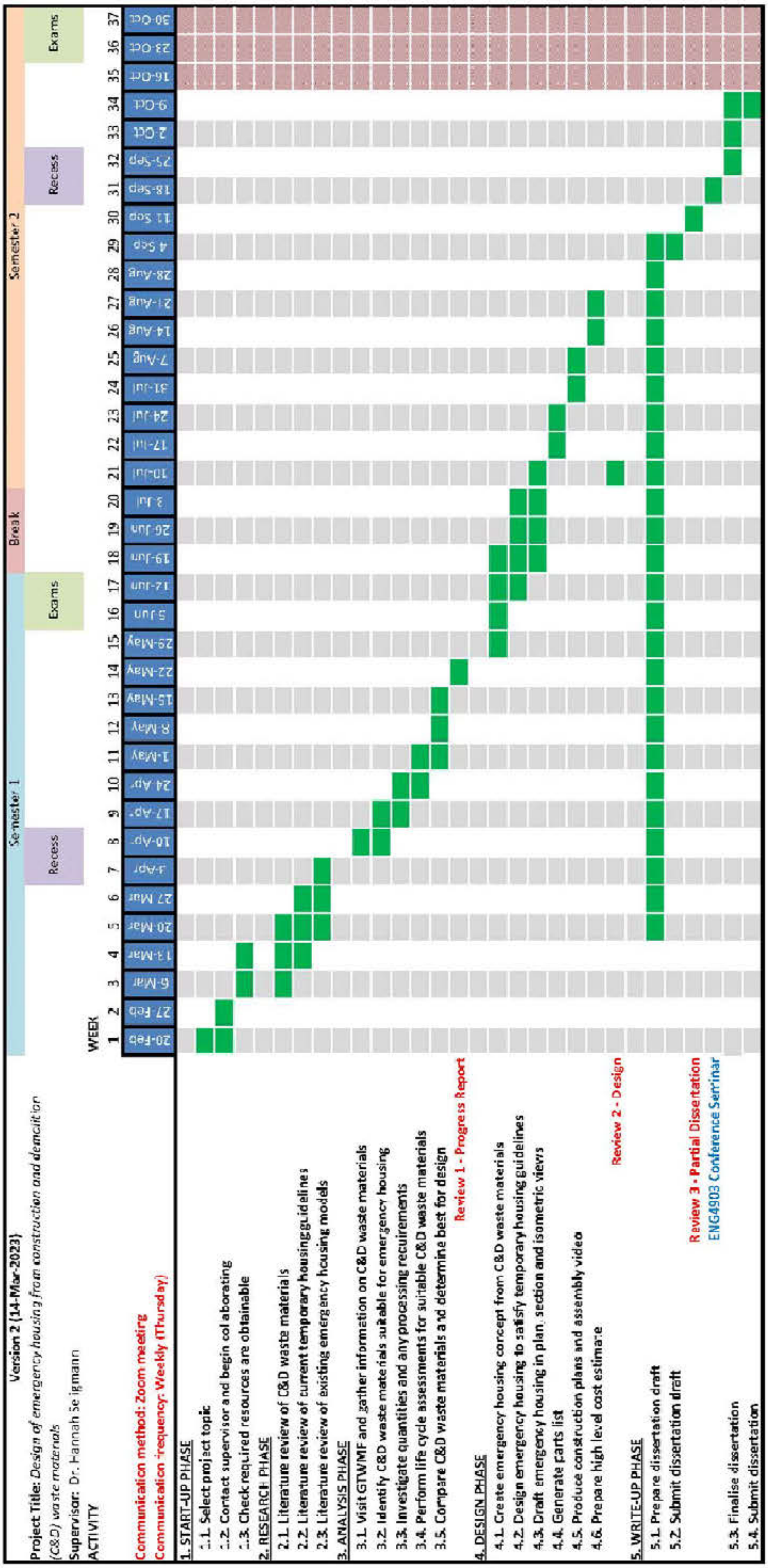
Risk Assessment [Ref Number: 2150]

Date Printed: Wednesday, 15 March 2023

Risk Matrix Level	
Very Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Medium	Task can proceed upon approval of the risk assessment by a Category 4 or higher delegate
High	Task can only proceed in extraordinary circumstances provided there is authorisation by the Vice Chancellor
Extreme	Task must not proceed. Appropriate and prompt action must be taken to reduce the risk to as low as reasonable practicable

ATTACHMENTS

Appendix C – Project Plan



Appendix D – Queensland Development Code MP 3.3

MP 3.3 – TEMPORARY ACCOMMODATION BUILDINGS AND STRUCTURES

1 **Purpose** 2
2 **Commencement** 2
3 **Application** 2
4 **Referral agency** 3
5 **Referenced standards and documents** 3
6 **Definitions** 3
Building Standards **5**
Removal or Demolition 5
Health and Amenity **6**
Siting requirements 6
Sleeping Compartments 6
Finishing 6
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Dust control 7
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MP 3.3 – TEMPORARY ACCOMMODATION BUILDINGS AND STRUCTURES

1 Purpose

The purpose of this Part is to specify minimum standards for *temporary accommodation buildings*.

2 Commencement

This Part —

(a) commences on 20 June 2014; and

(b) replaces the version of this Part published on 2 June 2010.

3 Application

(1) The *QDC*, other than MP 1.1, MP 1.2 and MP 1.3 where relevant and MP 3.3, do not apply to a *temporary accommodation building.*

(2) For section 30 of the *Building Act 1975*, MP 3.3 is a building assessment provision for *temporary accommodation buildings* other than a building:

(a) to which MP 5.6 "Pastoral Workers Accommodation Code" applies; or

(b) that is or forms part of a corrective services facility under the *Corrective Services Act 2006* or a detention centre under the *Juvenile Justice Act 1992.*

(3) MP 3.3 applies to a *temporary accommodation building,* which is intended for use on a site or approved for use on a site as specified in table T1, where a temporary accommodation building is:

(a) occupied or available for occupation by a person under an employment agreement; or

(b) occupied or available for occupation by a person in return for a rent; or

(c) intended for private and domestic residential use.

Table T1

Period of intended or approved use	Application of performance criteria of this code
Accommodation where there is an employment agreement or where a rent is paid	
42 *days* or less.	P20.
More than 42 *days*.	All criteria except P20.
Temporary accommodation buildings in lawful use on the day this code commences that are moved to a new site once within a two year period from the commencement date of this code.	For buildings intended or approved for use on site for up to (a) 112 *days* – P20; and (b) more than 112 *days* - All criteria except P2, P3, P5, P6 and P7.
Accommodation for private and domestic residential use	
Temporary accommodation buildings intended for uses specified in (3) (c).	P1 and P3.

4 Referral agency

The Local Government is a concurrence agency for any alternative solutions used to comply with performance criterion P1 under this part.

5 Referenced standards and documents

Number	Date	Title
AS 2890.1	1993	Parking facilities – off-street car parking

6 Definitions

Note

Italicised words within the body of the Part, other than legislation titles, are defined below.

Approval period means the period for which the *temporary accommodation building* is approved to remain onsite in accordance with section 67(1) of the *Building Act 1975*.

Bathing and sanitary facility means bathing, shower and water closet facilities provided for each three *bed*s or part thereof that includes –

(a) a dual flush water closet cistern and pan with a minimum floor area of 0.81m^2, one fixed wash basin with internal overflow relief facility and a water stop plug permanently attached to the basin; and
(b) a shower; and
(c) hot and cold water outlets to each shower with a shower rose having a minimum 3 star Water Efficiency Labelling and Standards rating; and
(d) a vanity mirror, a vanity shelf, a towel rail, a toilet roll holder, and a clothes hook; and
(e) where items (a) and (b) are in separate cubicles, such cubicles have doors able to be latched closed from the inside and removable from the outside; and
(f) a double power point.

BCA means the Building Code of Australia as defined by the *Building Act 1975*.

Communal facilities means any building which contains laundry, dining, sanitary, recreational facilities or the like but does not include uncovered recreational areas such as tennis courts, football fields or the like.

Bed means a piece of furniture in a *sleeping compartment* which is designed for or used by a person to sleep on.

Day means a calendar day.

Demolish means demolition and removal of a building or *structure* including all building services, footings, and debris.

Dining area means an area where meals are eaten at a table or a designated area used for dining.

Dining facility means an indoor *dining area* where all meals are provided along with dining utensils.

Ensuite means a private room that provides *bathing and sanitary facilities*.

Ground cover means –
(a) drought resistant vegetation; or
(b) mulch; or
(c) coarse aggregate of 15 mm nominal diameter; or
(d) a sealed surface such as concrete or other suitable material.

Industrial or development means work other than catering for or maintenance of *temporary accommodation buildings*.

Opening means doors, windows and other openings in external walls or roofs.

Outdoor space means a covered and paved outdoor area available for recreational use by *residents*.

QDC means Queensland Development Code.

Remove means removal of a building or *structure* including all building services, footings, and debris.

Resident means someone who sleeps in, or is accommodated in, a *temporary accommodation building.*

Short term temporary accommodation means accommodation provided for a period not exceeding 112 *days*

Sleeping compartment means a room which contains a *bed*.

Structure for the purposes of this standard includes a transportable or demountable building or a caravan which is fixed to the ground or supported by footings.

Temporary accommodation building means a building that is intended to be used on site or is approved for use on a site for a limited period and
(a) contains a *sleeping compartment*, whether or not it is used; or
(b) is a building that contains facilities *required* by this part to service a *sleeping compartment*.

PERFORMANCE CRITERIA		ACCEPTABLE SOLUTIONS	
	Building Standards		
	Removal or Demolition		
P1	*Temporary accommodation buildings* remain located on a site for an appropriate duration.	**A1**	*Temporary accommodation buildings,* after an approved duration of no more than 24 months, are *removed* from the site or *demolished.*
	Building Code of Australia		
P2	*Temporary accommodation buildings* comply with the performance criteria of the *BCA* except for JP2 and JP3 of *BCA* Volume 1 and P2.6.2 of *BCA* Volume 2, where the temporary accommodation building is occupied, or available for occupation, by a person: (a) under an employment agreement; or (b) in return for the payment of rent.	**A2**	*Temporary accommodation buildings* which are: (a) class 2 to 9 buildings - comply with the following deemed-to-satisfy provisions of the *BCA* Volume 1: (i) sections A to I; and (ii) parts J1.1 to J1.5. (b) class 1 or 10 buildings - comply with the following deemed-to-satisfy provisions of the *BCA* Volume 2: (i) section 1 and parts 3.0 to 3.11; and (ii) 3.12.1.1 to 3.12.1.4 and 3.12.1.6.
P3	*Temporary accommodation buildings* other than those in performance criteria P2 comply with the performance requirements of the *BCA* except for FP5.1 to FP5.6, JP2 and JP3 of *BCA* Volume 1 and P2.4.6 and P2.6.2 of *BCA* Volume 2.	**A3**	*Temporary accommodation buildings* which are: (a) class 2 to 9 buildings - comply with the following deemed-to-satisfy provisions of the *BCA* Volume 1: (i) sections A to E and sections G, to I; and (ii) parts F1 to F4; and parts J1.1 to J1.5 (b) class 1 or 10 buildings - comply with the following deemed-to-satisfy provisions of the *BCA* Volume 2: (i) section 1, parts 3.0 to 3.7 and parts 3.9 to 3.11; and (ii) parts 3.8.1 to 3.8.5;

			3.12.1.1 to 3.12.1.4 and 3.12.1.6.

Health and Amenity

	Siting requirements		
P4	Except for *short term temporary accommodation, temporary accommodation buildings* are placed in a suitable location on the site to ensure provision and maintenance of healthy conditions with visual and acoustic privacy from *industrial or development* activity.	**A4**	Except for *short term temporary accommodation,* every *temporary accommodation building* is placed – (a) on a base of concrete, coarse gravel or the like, raised at least 150mm above the surrounding ground level; or (b) on a site drained in accordance with the *BCA* Volume 2 Part 3.1.2; and (c) more than 45m from any *industrial or development* activity.
	Sleeping Compartments		
P5	*Sleeping compartments* in *temporary accommodation buildings*: (a) have sufficient area to provide a comfortable and healthy living environment appropriate to the number of occupants of the *sleeping compartment*; and (b) have adequate power outlets for appliances; and (c) are provided with separation between male and female accommodation; and (d) are provided with adequate personal space and facilities for each *resident*.	**A5**	Every *sleeping compartment* in a *temporary accommodation building* – (a) has a double power point; and (b) has walls extending from the floor to the ceiling separating each *sleeping compartment*; and (c) has a minimum floor area of $5.6m^2$ for each *bed*
	Finishing		
P6	The internal walls of a *temporary accommodation building* are constructed to minimise the accumulation of dust, moisture, litter or waste and prevent harbourage of pests or anything that would adversely affect the hygienic condition of the building.	**A6**	Internal walls of *temporary accommodation buildings* are lined with fibre cement sheeting, plasterboard, timber or the like.

	Pest control		
P7	*Openings* in the external walls of *temporary accommodation buildings* are adequately protected from airborne insects.	**A7**	*Temporary accommodation buildings* which are not air conditioned have fly screens fitted to every external opening of – (a) a *sleeping compartment*, other than a door, window or other opening to a screened verandah; and (b) facilities shared by, or intended to be shared by, *residents* who use different *sleeping compartments* in a *temporary accommodation building*.
	Dust control		
P8	Except for *short term temporary accommodation,* surfaces surrounding *temporary accommodation buildings* are suitably sealed, taking into account the duration the *temporary accommodation buildings* will remain on the site, to minimise airborne dust.	**A8**	Except for *short term temporary accommodation, temporary accommodation buildings* are surrounded by at least 6m of *ground cover* onsite where grounds are unsealed.
	Vehicle access		
P9	Except for *short term temporary accommodation,* onsite roads, driveways, vehicle-circulation areas and vehicle parking bays associated with a *temporary accommodation building* are adequately prepared and have surfaces suitable for vehicular access.	**A9**	Except for *short term temporary accommodation,* onsite roads, driveways, vehicle-circulation areas and vehicle parking bays comply with AS2890.1-1993 if they are associated with a *temporary accommodation building* – (a) of more than 100 *beds*; or (b) with an *approval period* of more than six months;
	Outdoor amenity		
P10	Except for *short term temporary accommodation,* a *temporary accommodation building* provides suitable *outdoor space* with a sealed surface for the recreational use of *residents.*	**A10**	Except for *short term temporary accommodation,* each *sleeping compartment* of a *temporary accommodation building* is provided with an outdoor area with a sealed floor protected from the weather by a roof and has – (a) access to an *outdoor space*, within 45m from the entry door of a *sleeping compartment*, with a floor area of not less than

			$30m^2$ for every 20 *sleeping compartments* or part thereof; or (b) for *sleeping compartments*: (i) facing each other and not more than 3 metres apart, a verandah attached to the *temporary accommodation building* with a floor area of not less than $4.5m^2$, with a minimum length of 3m and a minimum width of 1.5m; and (ii) not facing each other or more than 3m apart, a verandah attached to the *temporary accommodation building* with a floor area of not less than $4.5m^2$, with a minimum length of 2.5m and a minimum width of 1.8m.
	Weather protection		
P11	Except for *short term temporary accommodation,* the path between a *sleeping compartment* and any *communal facilities* on the site are: (a) suitably protected from the weather; and (b) where immediately adjacent to a *sleeping compartment*, sealed with a suitable material to reduce noise generated by pedestrian traffic.	**A11**	Except for *short term temporary accommodation,* any *communal facilities* on the site are connected to every *sleeping compartment* by a covered walkway which: (a) is not less than 1.5m wide; and (b) has a surface sealed with concrete or bitumen; and (c) is protected from the weather by an impervious roof.

Facilities

	Bathing and sanitary facilities		
P12	*Residents* of *temporary accommodation buildings* are provided with *bathing and sanitary facilities* for personal hygiene and that will – (a) provide users with adequate privacy; and (b) be located a convenient distance from each *sleeping compartment*.	**A12**	*Residents* of *temporary accommodation buildings* – (a) have access to a *bathing and sanitary facility* with separating walls extending from the floor to the ceiling – (i) located within the building in which the *sleeping compartment* is located;

			or (ii) in a separate building located not more than 20m from the door of the *sleeping compartment* that they occupy; or (b) have an *ensuite* within the *sleeping compartment* that they occupy.
	Laundry		
P13	Adequate laundry facilities are provided for *residents* and conveniently located from *temporary accommodation buildings* with the capacity to cater for the number of *residents* expected to use the facilities at any one time.	**A13**	*Temporary accommodation buildings* have laundry facilities that – (a) are located not more than 60m from a *sleeping compartment*; and (b) have one automatic washing machine provided with each eight *beds* or part thereof; and (c) have one fixed wash tub provided with hot and cold piped water with each 20 *beds* or part thereof; and (d) have one double power point for appliances; and (e) clothes drying facilities comprising: (i) clothes line or hoist with a minimum of 7.5m of line per *bed*; or (ii) one heat operated drying cabinet or appliance capable of holding a minimum of 6.8kg for each 8 *beds*
	Kitchen		
P14	*Residents of temporary accommodation building* have access to adequate facilities to prepare and cook and store food.	**A14**	*Residents* of a *temporary accommodation building* have access to – (a) a kitchen food preparation area with - (i) at least one double power point where the building or *structure* is connected to a consumer mains power supply; and

(ii) a storage cupboard of not less than 0.7m3; or

(b) a *dining facility* where all meals are provided; or

(c) food catered for externally.

Refrigeration facilities

P15 Adequate food and drink refrigeration storage is provided for *residents* of *temporary accommodation buildings.*

A15 *Sleeping compartments* are provided with –

(a) a 100 litre refrigerator in each *sleeping compartment*; or

(b) access to a 500 litre refrigerator for every 20 *beds* serviced with amenities by *temporary accommodation buildings* or part thereof within a 20m distance of each *sleeping compartment*.

Dining facilities

P16 Adequate *dining facilities* are provided for *residents*, in a convenient location to *sleeping compartments*, with the capacity to cater for the number of *residents* expected to use the facilities at any one time.

A16 *Temporary accommodation buildings* provide *dining facilities,* at a ratio of 0.6 of the total number of *residents* accommodated, which –

(a) have a seat for each *resident* with tables providing 600mm table-length per *bed*; and

(b) have a floor area not less than $18.4m^2$ for each 20 *residents*, with an additional $0.92m^2$ for every *resident* in excess of 20 persons; and

(c) are located no more than 70m from the door of each *sleeping compartment* served.

Storage facilities

P17 Weatherproof and lockable storage facilities, appropriate to the number of *residents* accommodated on the site, are provided.

A17 Unless the *accommodation unit* is for the exclusive use of one *resident*, for each *resident* accommodated on the site, a personal storage unit is provided which is:

(a) weatherproof; and

(b) lockable; and

(c) at least 1.5m in height; and

(d) at least $0.7m^3$ in volume.

Communications

P18 Adequate communication facilities that

A18 Where internet and telephone

	can be used with a reasonable level of privacy to conduct personal conversations are provided for *residents* of *temporary accommodation buildings*.		coverage is available, internet and telephone communication facilities are provided as follows – (a) at least one internet access facility, comprising of an internet connection point for a computer per 25 *beds* provided; and (b) at least one communal computer connected to the internet per 100 *beds*, for use by the *residents,* and (c) at least one communal telephone per 100 *beds* provided; and (d) telephones are to be provided in booths or in a suitable location to allow users reasonable privacy.

Sustainable Building Measures

Energy and water resources

P19	A *temporary accommodation building* provides energy and water efficiency appropriate to the – (a) class of the building; and (b) length of the *approval period*.	**A19**	*Temporary accommodation buildings* have – (a) energy efficient lighting complying with MP 4.1 of the *QDC*; and (b) toilet cisterns complying with MP 4.1 of the *QDC*.

Requirements for Certain Short Term Temporary Accommodation Buildings

P20	A *temporary accommodation building* or *structure* must: (a) be structurally sound and capable of withstanding the loadings likely to arise from its use; and (b) reasonably provide for the: (i) safety of persons to be accommodated in the building or *structure* if there is a fire including, for example, means of egress; (ii) prevention and suppression of fire; (iii) prevention of the spread of fire;	**A20**	A *temporary accommodation building* or *structure* which is: (a) intended or approved to remain on a site for periods of 42 *days* or less; or (b) existing; and (i) in lawful use on the day this code commences; and (ii) is moved to a new site only once within a two year period from the commencement of this code; and (iii) intended or approved to

(iv) health and amenity of persons to be accommodated in the building or *structure*.

remain on a site for periods of 112 *days* or less;

complies with sections B, C, D, E and F (except Part F5) of Volume 1 of the *BCA* or Volume 2 of the *BCA* (except Parts 3.7.4, 3.8.6 and 3.12) relevant to the class of building.

Version history

Version	Commencement date	Publication date
1.0	1 July 2010	2 June 2010

Appendix E – Temporary Accommodation Buildings Checklist

Form 24 Temporary accommodation buildings checklist

Queensland Government

This form is to be used for the purpose of the completion of a code checklist for a temporary accommodation building under section 89 of the Building Regulation 2021.

The requirement applies to new temporary accommodation buildings intended to remain on site for periods exceeding 42 consecutive days.

For buildings intended to remain on site for 42 consecutive days or less only some of the requirements of the Queensland Development Code Mandatory Part 3.3 – *Temporary Accommodation Buildings and Structures* (MP 3.3) apply (refer to A20 of MP 3.3).

For existing temporary accommodation buildings which were relocated before 1 July 2012, only some of the requirements of MP 3.3 apply.

Additional explanatory information on temporary accommodation buildings is included in the Appendix at the end of this form.

Requirements	[1]Other (please specify) or comments
Siting *(This requirement does not apply to some short-term temporary accommodation. Refer to notes.)*	
Has the temporary accommodation building been:	
(a) placed on a base of concrete, coarse gravel or similar base material *(if yes, go to next section—Sleeping compartments)*	○ Yes ○ No
(b) raised at least 150 mm above the surrounding ground level	○ Yes ○ No
(c) placed at least 45 metres away from work activities (other than catering for or maintenance of temporary accommodation buildings) on the site?	○ Yes ○ No
Sleeping compartments	
Has the sleeping compartment been provided with:	
(a) a double power point	○ Yes ○ No
(b) walls extending from the floor to the ceiling separating each sleeping compartment	○ Yes ○ No
(c) a minimum floor area of 5.6 m² for each bed?	○ Yes ○ No
Finishing	
Are internal walls of the buildings lined with fibre cement sheeting, plasterboard, timber or the like?	○ Yes ○ No
Pest control	
Is the building air conditioned? *(if yes, go to next section—Dust control)*	○ Yes ○ No
If the building is not air conditioned, does every door and window (other than a door, window or other opening from a sleeping compartment to a screened verandah) of a sleeping compartment or shared facility have flyscreens?	○ Yes ○ No
Dust control *(This requirement does not apply to some short-term temporary accommodation. Refer to notes.)*	
Is the ground surrounding the temporary accommodation building sealed or does the first 6 metres have ground cover such as mulch or coarse aggregate?	○ Yes ○ No
Vehicle access *(This requirement does not apply to some short-term temporary accommodation. Refer to notes.)*	
If the temporary accommodation building has an approval period of more than six months or more than 100 beds, are on-site roads, driveways, vehicle circulation areas and parking bays in accordance with AS2890.1-1993?	○ Yes ○ No

Requirements	[1]Other (please specify) or comments
Outdoor amenity *(This requirement does not apply to some short-term temporary accommodation. Refer to notes.)*	
Does each sleeping compartment have an outdoor area with a sealed floor protected from the weather by a roof?	○ Yes ○ No
Do the sleeping compartments:	
(a) have access to an outdoor space, within 45 metres from the entry door of a sleeping compartment, with a floor area of not less than 30 m² for every 20 sleeping compartments or part thereof *(if yes, go to next section—Weather protection)*	○ Yes ○ No
(b) face each other and are less than 3 metres apart, have a verandah attached to the temporary accommodation building with a floor area of not less than 4.5 square metres, with a minimum length of 3 metres and a minimum width of 1.5 metres *(if yes, go to next section—Weather protection)*	○ Yes ○ No
(c) not face each other or are more than 3 metres apart, have a verandah attached to the temporary accommodation building with a minimum floor area of 4.5 square metres, minimum length of 2.5 metres and a minimum width of 1.8 metres?	○ Yes ○ No
Weather protection *(This requirement does not apply to some short-term temporary accommodation. Refer to notes.)*	
Are communal facilities connected to every sleeping compartment by a covered walkway which:	
(a) is not less than 1.5 metres wide	○ Yes ○ No
(b) has a concrete or bitumen surface	○ Yes ○ No
(c) is protected from the weather by an impervious roof covering?	○ Yes ○ No
Bathing and sanitary facilities	
Does each sleeping compartment have an ensuite or communal facilities with:	
(a) a double power point	○ Yes ○ No
(b) hot and cold water outlets to each shower with a shower rose	○ Yes ○ No
(c) a vanity mirror, vanity shelf, towel rail, toilet roll holder and clothes hook	○ Yes ○ No
(d) a shower	○ Yes ○ No
(e) a dual flush water closet cistern and pan with a minimum floor area of 0.81 square metres	○ Yes ○ No
(f) one fixed wash basin with internal overflow relief facility and a water stop plug permanently attached to the basin	○ Yes ○ No
(g) if items (d), (e) or (f) are in separate cubicles, cubicle doors able to be latched closed from the inside and removable from the outside?	○ Yes ○ No
If communal facilities are provided are they:	
(a) in a building which is less than 20 metres from the door of the occupied sleeping compartment or located in the same building as the sleeping compartment	○ Yes ○ No
(b) separated by walls extending from the floor to the ceiling between individual facilities?	○ Yes ○ No
Laundry	
Are laundry facilities located less than 60 metres from a sleeping compartment?	○ Yes ○ No

Requirements	¹Other (please specify) or comments
Do the laundry facilities have:	
(a) one automatic washing machine provided with each 8 beds or part thereof	◯ Yes ◯ No
(b) one fixed wash tub provided with hot and cold piped water with each 20 beds or part thereof	◯ Yes ◯ No
(c) one double power point for appliances	◯ Yes ◯ No
(d) clothes drying facilities comprising clothes line or hoist with 7.5 metres of line per bed or one 6.8 kilogram heat operated drying cabinet or appliance for every 8 beds?	◯ Yes ◯ No
Kitchen	
If a communal kitchen is not provided or food is not catered for externally, is there a food preparation area with a:	
(a) double power point	◯ Yes ◯ No
(b) storage cupboard of at least 0.7 m^2?	◯ Yes ◯ No
Refrigeration facilities	
Does each sleeping compartment have:	
(a) a 100 litre refrigerator (if yes, go to next section—Dining facilities)	◯ Yes ◯ No
(b) access to a 500 litre refrigerator for each 20 beds or part thereof, within a 20 metre distance of each sleeping compartment?	◯ Yes ◯ No
Dining facilities *(There are specific area requirements for communal dining facilities. Refer to A16 of MP 3.3)*	
Are communal dining facilities provided and located less than 70 metres from sleeping compartments?	◯ Yes ◯ No
Storage facilities	
If the accommodation unit is for use by more than one resident, does each resident have a personal storage unit which is weatherproof, lockable, at least 1.5 metres in height and at least 0.7 m^3 in volume?	◯ Yes ◯ No
Communications *(The specific requirements for communications facilities are dependent on the number of beds provided. Refer to A18 of MP 3.3 for details.)*	
Do you have access to the internet and telephone where coverage is available?	◯ Yes ◯ No

APPENDIX

1. The code for temporary accommodation buildings allows 'other' methods to be used which, in the opinion of a building certifier, meet the performance criteria of the code. 'Other' methods can only be approved by a building certifier.
2. Temporary accommodation buildings must meet most of the requirements of the National Construction Code, Building Code of Australia including smoke alarms, emergency exits and in some cases fire-rated wall construction. The extent to which these requirements must be met is dependent on the class of the building. Please refer to the Building Code of Australia for further details published on the Australian Building Codes Board website.
3. This checklist provides a summary of the requirements of MP 3.3 of the Queensland Development Code. For full details of the code requirements refer to MP 3.3. A full copy of the code can be viewed at www.epw.qld.gov.au.
4. Noncompliance with MP 3.3 is an offence under the *Planning Act 2016*. The person in control of the site is responsible for ensuring that the code requirements, including the display of this checklist in a conspicuous location, are being provided. Any person who believes the requirements of the code are not being met can refer the matter to the relevant local government in the area for investigation.

PRIVACY NOTICE

The Department of Energy and Public Works is collecting personal information as required under the *Building Act 1975*. This information may be stored by the Department, and will be used for administration, compliance, statistical research and evaluation of building laws. Your personal information will be disclosed to other government agencies, local government authorities and third parties for purposes relating to administering and monitoring compliance with the *Building Act 1975*. Personal information will otherwise only be disclosed to third parties with your consent or unless authorised or required by law.

Appendix F – Rawlinsons Wage & Plant Hire Rates

WAGE RATES

The wage rates given hereafter are those used in the price build-up of the various trade sections of Detailed Prices. They are considered to be typical rates for works in the $250,000 to $1,500,000 range.

Also stated is the percentage allowance included in the price build-up for Builder's head office overheads and profit.

	COSTING RATE						ALLOWANCES FOR BUILDER'S OVERHEADS AND PROFIT
	Adelaide	**Brisbane**	**Hobart**	**Melbourne**	**Perth**	**Sydney**	
	$/hour	**$/hour**	**$/hour**	**$/hour**	**$/hour**	**$/hour**	
BUILDING TRADES							+7.5%
Labourer - Generally	58.00	59.50	62.00	61.00	66.00	65.00	
Tradesman -							
Generally	62.50	62.00	69.00	63.50	73.25	65.00	
Bricklayer	62.50	66.50	68.00	64.50	73.25	65.00	
Carpenter	63.00	66.50	70.00	61.00	74.00	65.00	
Joiner	62.00	66.50	75.50	64.50	74.00	65.00	
Glazier	62.00	63.00	73.00	64.00	74.00	60.00	
Painter	62.00	63.00	61.00	64.00	73.25	60.00	
PLUMBING, DRAINAGE							+7.5%
Labourer	58.00	59.50	62.00	61.00	66.00	65.00	
Plumber	70.00	71.00	90.00	73.75	81.25	85.00	
ELECTRICAL SERVICES							+5.0%
Electrician	76.50	74.00	93.00	72.75	84.25	85.00	
MECHANICAL SERVICES							+5.0%
Generally	71.00	74.00	91.00	72.75	78.00	75.00	

PLANT HIRE RATES

GENERAL AND SMALL PLANT

Hire rates for extended periods would generally be reduced.

The rates exclude the Goods and Services Tax (G.S.T.).

ADD extra for :
- Delivery and return.
- Erection and dismantling where applicable.
- Operators.
- Fuel, power and other consumables.

	$/day
ACROW PROPS	
1.6m to 3.3m	5.00
AIR COMPRESSORS	
Portable :	
4 litre/second, petrol or electric	50-60
6 litre/second, petrol or electric	55-65
Silenced :	
47 litre/second, diesel	115-155
61 litre/second, diesel	115-155
83 litre/second, diesel	135-175
189 litre/second, diesel	200-250
425 litre/second, diesel	250-350
AIR HOSES	
19mm x 18m	13-17
50mm x 18m	45-55
AIR TOOLS	
Breaker :	
Small, 18 litre/second	35-45
Medium, 26 litre/second	50-60
Large, 28 litre/second	60-75
Chipping hammer, 12 litre/second	40-55
Spade bits	10-12
Drills :	
6mm/13mm, 8 litre/second	35-45
19mm/32mm, 32 litre/second	55-65
Grinders, 9 litre/second	40-50
Impact Wrench :	
13mm, 11 litre/second	40-50
19mm, 14 litre/second	45-55
25mm, 24 litre/second	50-60
38mm, 47 litre/second	80-95
Orbital Sander	35-45
Rock Drill :	
Small, 12 litre/second	35-45
Medium, 21 litre/second	50-65
Drill Steels -	
Up to 1.8m	15-20
1.8 to 3.0m	15-20
Sander, 18 litre/second	28-38
Scabbler :	
Single held, 4 litre/second	60-75
Triple head, wall, 11 litre/second	75-90
Multiple, 5 head, floor, 94 litre/second	270-310

	$/day
CONCRETE AND MASONRY EQUIPMENT	
Brick/Block splitter	35-45
Concrete Mixer (petrol)	35-50
Saws (excluding blades) :	
Brick (electric, petrol)	130-150
Concrete	105-135
Diamond blade 305mm	40-50
Trowelling machine	75-85
Vibrators :	
Drive unit (petrol)	65-75
Immersion vibe shaft and head	70-85
Shaft extension	40-50
CHAIN SAW	60-80
COMPACTION EQUIPMENT	
Plate compactor :	
Light (petrol)	70-85
Medium/heavy (diesel)	120-160
DEHUMIDIFIER	50-60
ELECTRIC TOOLS AND EQUIPMENT	
Drills (electric)	35-45
Kango hammer	60-70
Extension leads, 30m :	
Single phase	7-11
Three phase	30-40
Sanders :	
100mm belt	25-35
175mm disc	25-35
200mm floor	60-80
Orbital	20-30
FLOOR GRINDER (petrol, electric)	70-85
FLOOR SANDER	60-80
FLOOR TILE STRIPPER	80-100

PLANT HIRE RATES

GENERAL AND SMALL PLANT (cont'd)

	$/day
GENERATORS AND LIGHTING	
Generators :	
Unsilenced, petrol -	
2 KVA, 1 phase, 8 amp	40-50
3 KVA, 1 phase, 12 amp	50-60
5 KVA, 1 phase, 20 amp	70-80
8 KVA, 1 phase, 20 amp	105-135
Silenced, diesel -	
6 KVA, 1 phase, 24 amp	70-80
8 KVA, 1 phase, 32 amp	70-85
15 KVA, 3 phase, 20 amp	80-95
20 KVA, 3 phase, 27 amp	100-115
35 KVA, 3 phase, 47 amp	130-145
50 KVA, 3 phase, 69 amp	145-170
60 KVA, 3 phase, 83 amp	180-205
80 KVA, 3 phase, 111 amp	200-230
100 KVA, 3 phase, 139 amp	230-250
200 KVA, 3 phase, 278 amp	370-420
350 KVA, 3 phase, 435 amp	480-550
Silenced, bio-diesel -	
12 KVA	85-110
20 KVA	95-135
37 KVA	135-160
50 KVA	165-200
80 KVA	220-260
120 KVA	310-365
300 KVA	395-450
365 KVA	450-530
550 KVA	670-800
Floodlights :	
On stand	15-20
Portable	20-35
Lighting towers, mobile, hydraulic	100-340
HANDLING, HOISTING AND LIFTING EQUIPMENT	
Belt conveyor :	
10.0m	145-170
Chain block :	
1 tonne	45-50
2 tonne	65-75
3 tonne	75-85
5 tonne	100-130
Hoists and hoisting - refer Preliminaries	
Jacks, hydraulic :	
11 tonne	35-45
20 tonne	50-60
50 tonne	70-85
PUMPS	
Centrifugal pumps :	
50mm, petrol, 525 litres/minute	60-70
50mm, diesel, 525 litres/minute	65-75
Centrifugal trash pumps :	
50mm, petrol, 525 litres/minute	65-70
75mm, petrol, 825 litres/minute	70-80
100mm, diesel, 1900 litres/minute	85-100
150mm, diesel, 5400 litres/minute	160-200
Diaphragm pumps :	
50mm, petrol, 150 litres/minute	80-90
75mm, diesel, 300 litres/minute	90-110

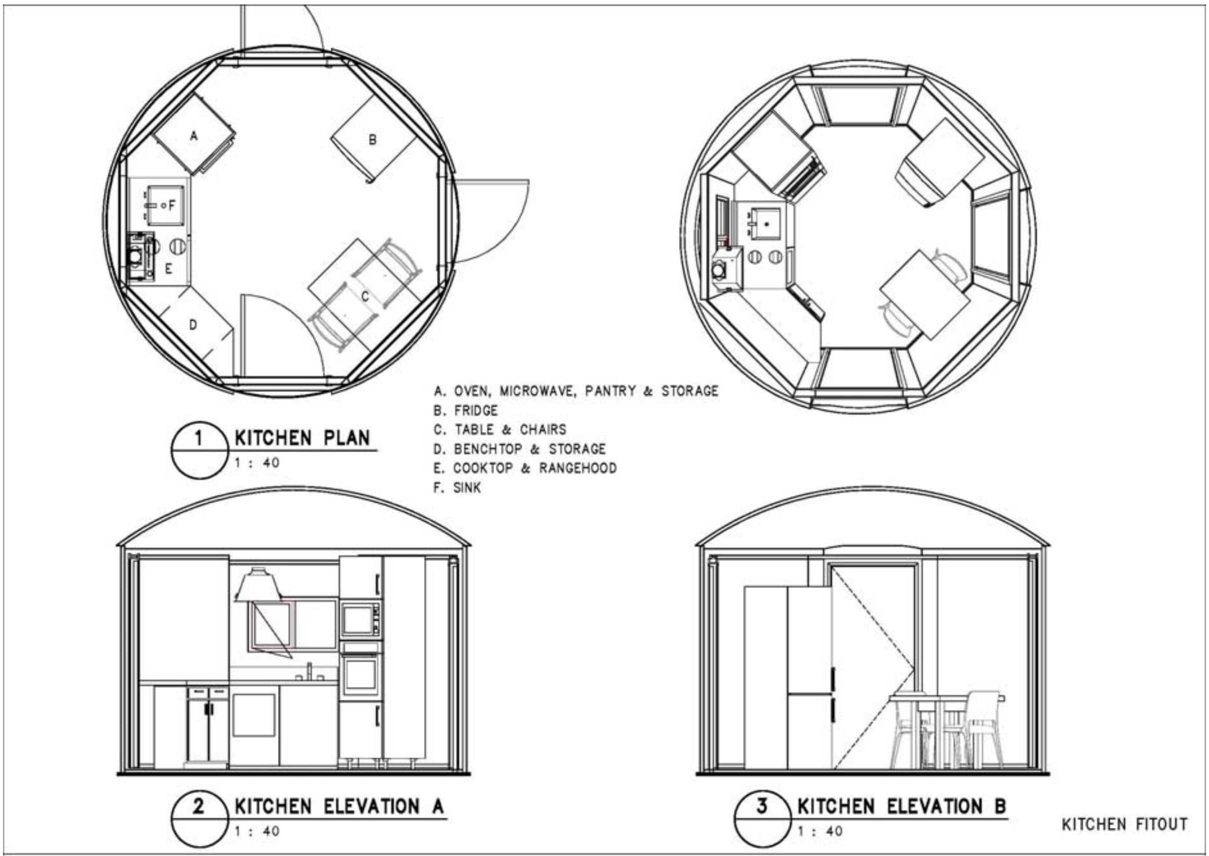
	$/day
PUMPS (cont'd)	
Hoses :	
Delivery -	
50mm x 15m	11-13
75mm x 15m	15-20
100mm x 15m	20-25
150mm x 15m	25-35
Suction -	
75mm x 6m	7-10
100mm x 6m	10-14
150mm x 3m	6-9
ROLLERS	
Pedestrian roller, 700mm, petrol	110-135
SKID STEER LOADERS	
Medium	200-250
Large	250-300
Extra Large	275-320
Rubber tracked	275-340
Medium with trailer	280-320
WATER TESTING	
Portable tubidity meter	70-80
WELDING EQUIPMENT	
Welders, diesel :	
300 amp	65-75
400 amp	95-115
Welders, electric :	
140 amp, single phase	45-55
200 amp, three phase	50-60
300 amp, three phase	70-85
400 amp, three phase	95-110
Welding leads	7-13
MISCELLANEOUS	
Barrows	15-17
Battery charger	20-25
Bitumen sprays :	
Hand	70-85
Power	90-115
Cleaning charge, additional per hour	35-40
Bolt cutters	21-23
Drain rods, 18m	24-26
Dumpy level	55-65
Earth auger :	
Hand	13-16
Petrol	70-95
Earth leakage unit	21-23
Fans, exhaust	50-70
Flashing lights (per week)	8-10
Ladders :	
3.0m/4.8m	19-21
4.2m/7.2m	25-30
5.4m/10.0m	33-40
Nail gun	50-60

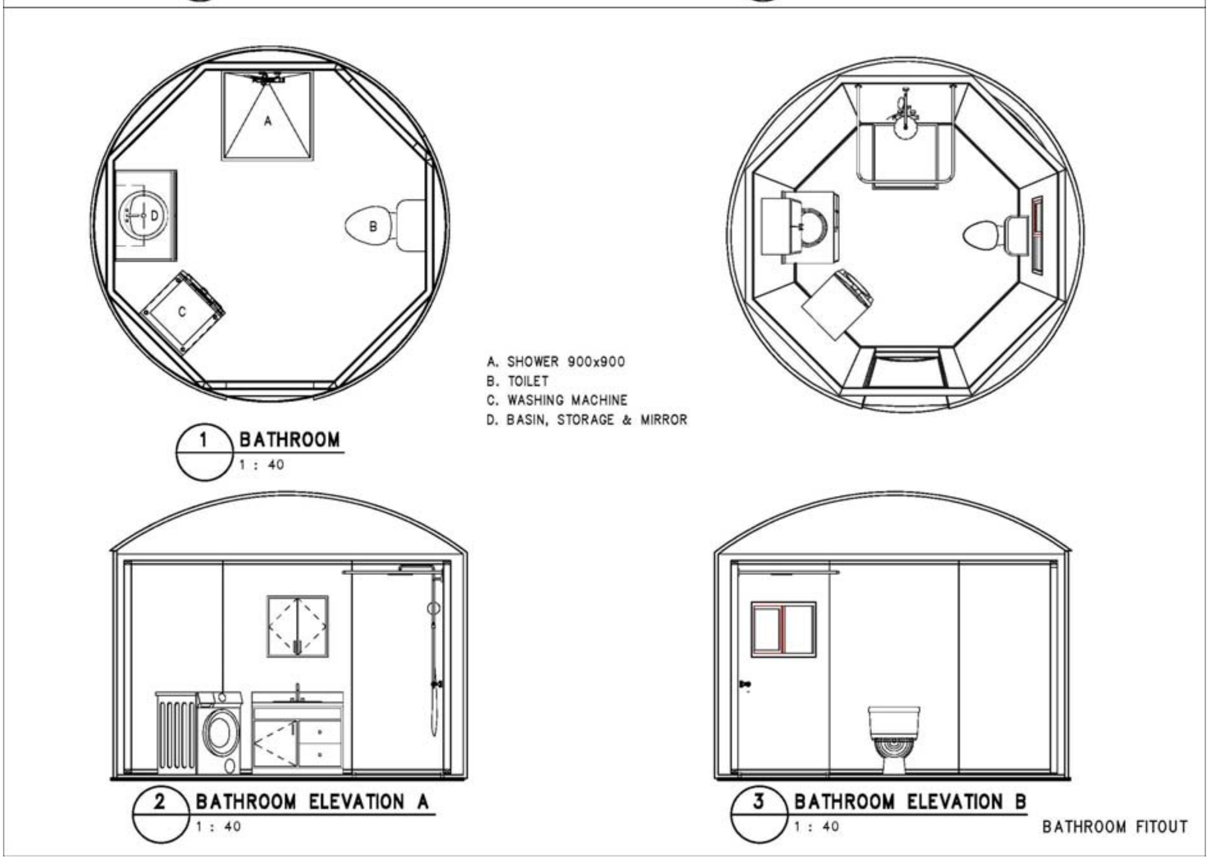
PLANT HIRE RATES

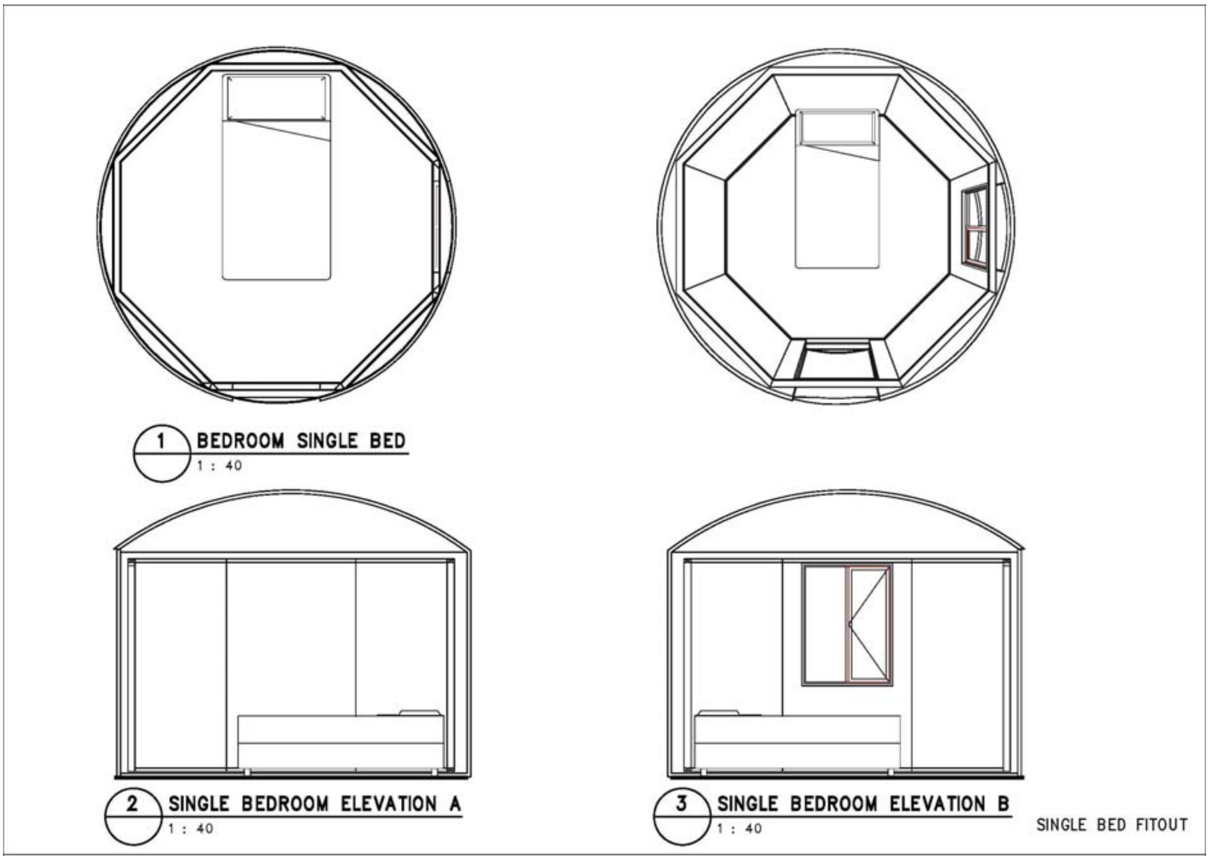
GENERAL AND SMALL PLANT (cont'd)

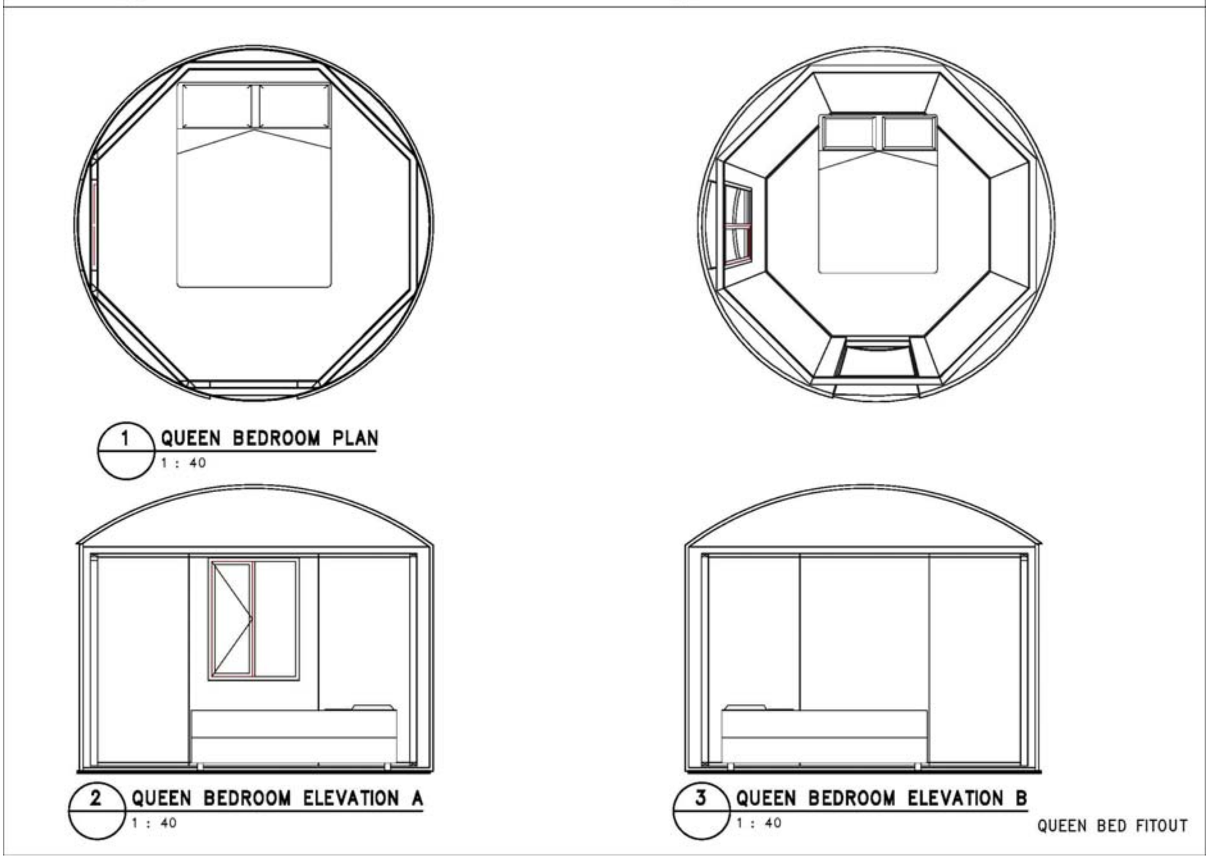
	$/day
MISCELLANEOUS (cont'd)	
Paint burner including gas	25-30
Penetrometer	17-19
Pipe bender, (hydraulic) up to 50mm	60-70
Pipe cutter, manual	35-40
Pipe threaders, electric :	
Up to 50mm	110-135
Up to 100mm	125-160
Pipe vice and stand	19-23
Planks (aluminium)	10-14
Ramset gun	55-70
Road warning signs	4.00
Space heater, 180000 BTU	65-80
Tarpaulin, 6m x 5.5m	21-24
Tension wrenches :	
13mm	19-23
19mm	25-28
25mm	35-40
Tile cutter, manual, ceramic	26-30
Tile saw, electric	75-90
Trestles :	
1.8m	10-15
2.4m	10-15
3.0m	15-20
3.6m	15-20
4.2m	15-20
Tube bender	20-25
Vacuum cleaner	50-70
Wallpaper stripper, electric	35-45
Water tank, 1500 litres	35-45
Witches hat (per week)	15.00

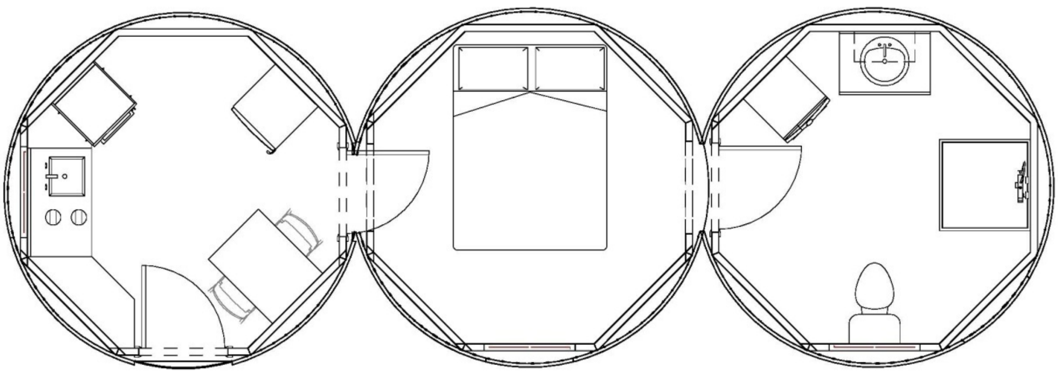
Appendix G – Design Drawings



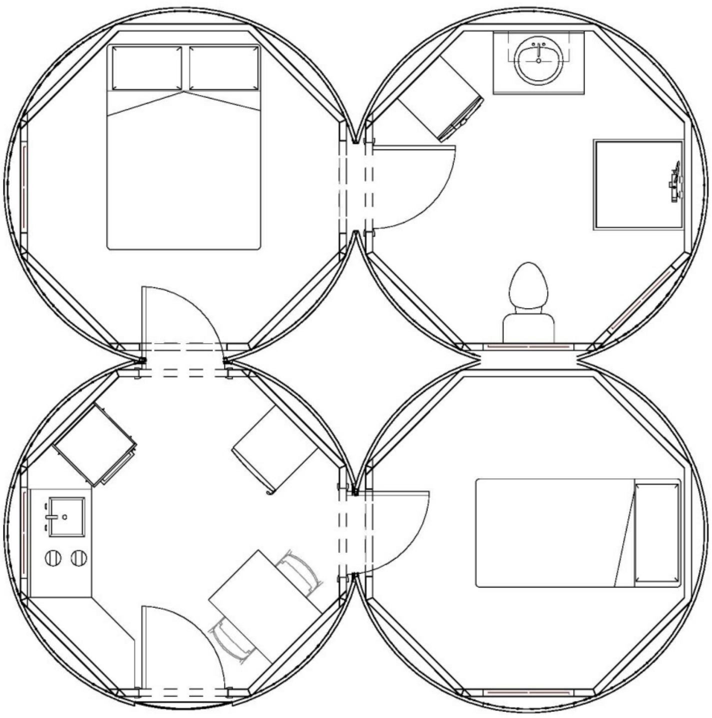



1 BEDROOM SINGLE BED
1 : 40
2 SINGLE BEDROOM ELEVATION A
1 : 40
3 SINGLE BEDROOM ELEVATION B
1 : 40
SINGLE BED FITOUT


1 QUEEN BEDROOM PLAN
1 : 40
2 QUEEN BEDROOM ELEVATION A
1 : 40
3 QUEEN BEDROOM ELEVATION B
1 : 40
QUEEN BED FITOUT

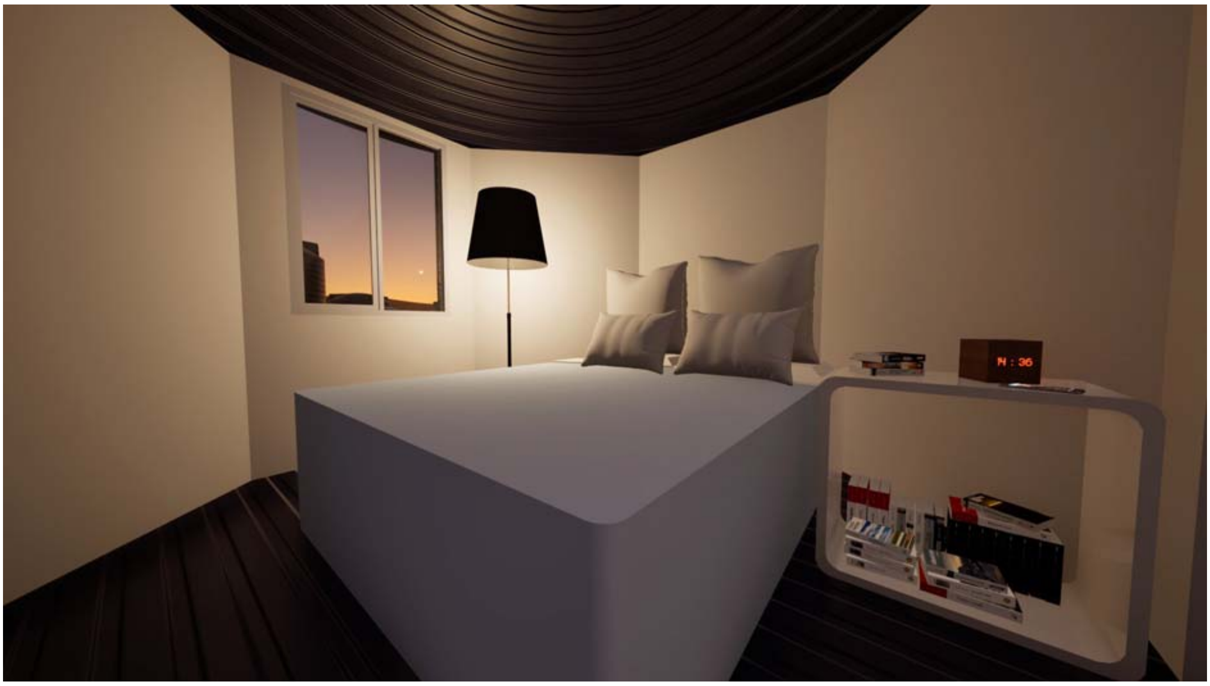


3 MODULE LAYOUT



4 MODULE LAYOUT

Appendix H – Design Renders



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