The feasibility of Wood Plastic Composites as building material for RDP houses in South Africa

by

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Declaration

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Summary

The South African Government is faced with numerous environmental, economic and social challenges. Invasive alien plants (IAPs) are environmental threats, which change the ecosystems they invade. The Working for Water (WfW) Programme is a pioneering environmental initiative working under the Department of Environmental Affairs (DEA), which aims to eradicate IAPs. The value-added industry (VAI) launched under the WfW Programme aims to use these cleared IAPs for economic benefits.

Plastic pollution is another global and national environmental issue caused by increasing population and industrialization. Numerous organizations have created awareness pertaining to this issue and the importance and benefits of recycling plastic waste.

The objective of this study was to assess the feasibility of producing wood plastic composites (WPCs) as a building material made from woody IAPs and recycled plastic for low cost buildings through a hypothetical small business initiative. WPCs can be deemed as green products since they use recycled material, renewable resources and minimize the impact they have on the environment.

Small business development is being encouraged to address the national unemployment rate. A feasibility study was conducted to assess the success of a proposed small WPC business. The feasibility study assumed that the project would take place in the Western Cape and *Acacia saligna* sourced along the Berg River and recycled LLDPE plastic from Bellville would be used for production. A survey was conducted in the Kayamandi Township to study the living conditions of people living in the RDP houses and observe any infrastructural defects. This would help identify a potential building structure replacement made from WPC material.

Based on the survey results, 14% of the respondents complained about defective ceiling boards thus, a potential building component was recognized.

Another part of the study was to determine the economic and financial perspective of manufacturing WPC ceiling boards, whereby the procurement costs of the raw material including the harvesting, purchasing and transport of these raw materials was considered. Two WPC ceiling boards with different dimensions were proposed. Type A being 1 m^2, with a thickness of 0.004 m (research prototype) and Type B with dimensions 3 m x 1.2 m x 0.004 m (commercial competitor) were proposed. Both options were found to be profitable for a small business initiative. The sample boards used for testing mechanical and physical properties exceeded the benchmark values of gypsum ceiling boards in all analysed properties.

The results showed that Type B boards could potentially replace the currently used gypsum ceiling boards of the same dimensions. In addition, the budgeted statement of profit or loss and comprehensive income showed a higher net profit after tax when compared to Type A boards. The mark-up percentages on cost of goods sold ensured that the selling prices per unit exceeded break-even prices resulting to selling prices (SP) of R90.16 and R120.76 for Type A boards and Type B boards per unit, respectively. This would allow the business to generate some profit. The net-present value (NPV) for the two board type investments were positive, however as a rule of thumb, the investment having the highest NPV value should be pursued. Therefore, the Type B boards would be recommended as a product to be sold in the small business. A sensitivity analysis was conducted to determine the effects of different input scenarios on the forecast break-even points. A change in selling price is highly sensitive as that determines the contribution margin of the business.

Key words: Wood plastic composites, woody invasive alien plants, plastic waste, feasibility study

Opsomming

Die Suid-Afrikaanse regering word deur talle omgewings-, ekonomiese en maatskaplike uitdagings gekonfronteer. Indringerplante (indringerplante) is omgewingsbedreigings wat die ekosisteme wat hulle binnedring verander. Die Working for Water (WfW) -program is 'n baanbrekende omgewingsinisiatief wat onder die Departement van Omgewingsake (DEA) werk, met die doel om IAP's uit te wis. Die toegevoegde waarde-industrie (VAI) wat in die loop van die WfW-program van stapel gestuur is, is daarop gemik om hierdie skoongemaakte IAP's vir ekonomiese voordele te gebruik.

Plastiese besoedeling is nog 'n wêreldwye en nasionale omgewingskwessie wat veroorsaak word deur toenemende bevolking en industrialisasie. Talle organisasies het bewustheid rakende hierdie kwessie en die belangrikheid en voordele van die herwinning van plastiekafval geskep.

Die doel van hierdie studie was om die lewensvatbaarheid van die vervaardiging van houtplastiese komposiete (WPC's) as 'n boumateriaal wat van hardhoutagtige IAP's en herwinde plastiek vir lae koste geboue vervaardig word, te evalueer deur middel van 'n hipotetiese klein ondernemingsinisiatief. WPC's kan as groen produkte beskou word, aangesien dit herwinde materiaal, hernubare hulpbronne gebruik en die impak wat dit op die omgewing het, tot die minimum beperk.

Die ontwikkeling van kleinsakeondernemings word aangemoedig om die nasionale werkloosheidsyfer aan te spreek. 'n Uitvoerbaarheidstudie is uitgevoer om die sukses van 'n voorgestelde klein WPC-onderneming te beoordeel. Die uitvoerbaarheidstudie het aanvaar dat die projek in die Wes-Kaap sou plaasvind en dat *Acacia saligna* langs die Bergrivier verkry word en dat herwinde LLDPE-plastiek uit Bellville vir produksie gebruik sou word. In die Kayamandi-township is 'n opname gedoen om die lewensomstandighede van mense wat in die Hop-huise woon, te ondersoek en infrastruktuurfoute op te spoor. Dit sal help om 'n moontlike vervanging van boustrukture uit WPC-materiaal te bepaal.

Op grond van die resultate van die opname het 14% van die respondente gekla oor gebrekkige plafonborde, dus is 'n potensiële boukomponent erken.

'n Ander deel van die studie was om die ekonomiese en finansiële perspektief van die vervaardiging van WPC-plafonborde vas te stel, waardeur die verkrygingskoste van die grondstof, insluitend die oes, aankoop en vervoer van hierdie grondstowwe, oorweeg is. Twee WPC-plafonborde met verskillende afmetings is voorgestel. Tipe A is 1 m^2, met 'n dikte van

0.004 m (navorsingsprototipe) en tipe B met afmetings 3 m x 1.2 m x 0.004 m (kommersiële mededinger). Daar is gevind dat beide opsies winsgewend is vir 'n klein ondernemingsinisiatief. Die monsterborde wat gebruik is vir die toets van meganiese en fisiese eienskappe het die normwaardes van gipsplafonborde in alle ontleed eienskappe oorskry.

Die resultate het getoon dat tipe B-planke moontlik die huidige gebruikte gipsplafonborde van dieselfde afmetings kan vervang. Daarbenewens het die begrote staat van wins of verlies en omvattende inkomste 'n hoër netto wins na belasting getoon in vergelyking met Tipe A-direksies. Die winspersentasies op die koste van die verkoopte goedere het verseker dat die verkooppryse per eenheid gelykbreekpryse oorskry het, wat die verkooppryse (SP) van onderskeidelik R90.16 en R120.76 beloop het vir tipe A-borde en tipe B-borde per eenheid. Dit kan die onderneming 'n bietjie wins oplewer. Die netto huidige waarde (NPV) vir die twee boordtypebeleggings was positief, maar as 'n reël, moet die belegging met die hoogste NPV-waarde nagestreef word. Daarom word die tipe B-planke aanbeveel as 'n produk wat in die kleinsakeonderneming verkoop sal word. 'n Sensitiwiteitsanalise is uitgevoer om die gevolge van verskillende inset scenario's op die voorspelde gelykbreekpunte te bepaal. 'n Verandering in verkoopprys is baie sensitief, aangesien dit die bydrae van die onderneming bepaal.

Sleutelwoorde: houtplastiese komposiete, hardhoutige indringerplante, plastiekafval, uitvoerbaarheidstudie

Dedications

This thesis is dedicated to my late parents Mandela and Mary Dlamini, my late stepmother Ntombizodwa Hlophe and late sister Philile Dlamini. Losing you at a young age made me an even stronger and wiser woman. You loved me whole-heartedly and dedicated your lives in ensuring that I would have a better future. I will forever be grateful. Thank you, Ngiyabonga kakhulu.

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Preface

This thesis is presented as a compilation of six chapters.

Chapter 1 **General introduction and project objectives**

Chapter 2 **Background**

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List of Abbreviations and Acronyms

CAGR	Compound Annual Growth Rate
DEA	Department of Environmental Affairs
DHS	Department of Human Settlements
DOL	Department of Labour
DTI	Department of Trade Industry
EBIT	Earnings Before Interest and Tax
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
NEF	National Empowerment Fund
NHBRC	National Home Builders Registration Council
NYDA	National Youth Development Agency
IAPs	Invasive Alien Plants
PE	Polyethylene
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RDP	Reconstruction and Development Programme
SAHRC	South African Human Rights Commission
SP	Selling Price
VAI	Value Added Industries
VAT	Value Added Tax
WfW	Working for Water
WPCs	Wood Plastic Composites

List of units

ha	Hectare
kg	Kilogram
m	Metre
mm	Millimetre
sqm	Square metre
t	Tonne

1 Introduction

The South African government is under pressure to address various environmental, economic and social issues faced by its citizens. This includes an increase in population, high unemployment rates, encroachment of invasive alien plants (IAPs) and plastic pollution. Unconventional solutions need to be encouraged in order to overcome some of these challenges.

The growing awareness of environmental degradation has resulted in concepts, such as green products, which can be described as products with less impact to the environment than their alternatives (Rahman 2002). Wood plastic composites (WPCs) can be deemed as such since they are made from renewable woody or non-woody plant fibres, which are incorporated with virgin or recycled plastic (Schwarzkopf and Burnard 2016).

WPC products can be used in many structural and non-structural applications, construction and automotive applications being the most common worldwide (Mantia and Morreale 2011), however, in South Africa the WPC concept is relatively new. The most common use for WPCs in South Africa include decking, indoor and outdoor furniture (Mudavanhu *et al.* 2017).

Only two WPC companies produce their products locally and their main focus is decking and outdoor furniture (de Kock 2017). This opens an opportunity for other products to be manufactured. The decision to use WPC products as an alternative should be based on achieving better performance, affordable price or reduced environmental impact (Schwarzkopf and Burnard 2016).

The purpose of this study is to develop an alternative building material (ceiling boards or wall panels) made from IAPs sourced along the Berg River and recycled linear low-density polyethylene (LLDPE) for low cost houses in South Africa. The produced composite material will reduce waste material categorized as undesirable and an environmental threat while creating economic opportunities

1.1 Problem statement

Invasive alien plants

Many IAPs from numerous parts of the world have been introduced into South Africa for different purposes, such as timber and crop species (Van Wilgen *et al.* 2001). Apart from their economic benefits, they tend to out-compete indigenous vegetation and have several negative impacts, such as: harming ecosystems and altering habitats, decreasing biological diversity, increasing fire intensity and lessening water availability (O'Donoghue and Fox 2009). IAPs, especially in the genera *Pinus, Hakea*, *Acacia* and *Eucalyptus* (particularly *Eucalyptus* *camaldulensis*) invade large parts of the Fynbos Biome (Van Wilgen 2009). The Berg and Breede Rivers in the Western Cape are the most heavily invaded catchments, followed by the George-Tsitsikamma region, Port Elizabeth coastal region and the Drakensberg escarpment (Le Maitre *et al.* 2000).

Of the approximated 9 000 plants introduced to the country, 198 are currently categorized as being invasive (DEA 2019a) and it is estimated that they cover 10 million ha of the country's total area (Meijninger and Jarmain 2014). These plants are spreading at a rapid rate and large amounts of money are invested into an environmental campaign called the "Working for Water" (WfW) programme aiming to eradicate the problem. Since its launch in 1995, the programme has created thousands of jobs (DEA 2019a).

Secondary industries based on cleared biomass were launched in 1998 under the WfW programme initiative to promote the utilization of cleared invasive alien plants and value-adding to biomass from the clearing operations. The Value-Added Industries (VAI) programme has three key objectives (DEA 2019b):

- Maximising the economic benefits, by extra job creation through the process of adding value to cleared IAP biomass
- Minimizing the net cost of clearing, thereby contributing to the sustainability of the programme.
- Reducing potential negative environmental impacts, such as fire damage, by leaving a small proportion of biomass after clearing has occurred.

Plastic waste

Over the past years, plastic production has grown at an exponential rate. In 1950, the world's population of 2.5 billion produced 2 million tonnes of plastic; in 2015, the global population of more than 7 billion people produced approximately 381 million tonnes of plastic (Ritchie 2018). The plastic packaging industry is the most dominant application industry, representing 26% of the total global use of plastic (MacArthur 2017; Plastic 2016). Single use plastic (straws, bottles, takeaway packaging containers) are considered as one of the main reason for the increasing levels of plastic pollution (PlasticsSA 2019).

The total plastic consumption for 2018 in South Africa was 1.88 million tonnes, of which 352 000 tonnes were recycled (PlasticsSA 2019). In that year, South Africa had with 46.3% a higher recycling rate than Europe (31.1%) (PlasticsSA 2019). The reason could be that the recycling industry in South Africa is mostly based on monetary benefits, yet in Europe most people are environmentally cautious and some municipal solid waste is incinerated for energy supply (MVB

2008). Recycling has created job opportunities for thousands of people in recycling factories, or as self-employed waste pickers or collectors in South Africa.

In South Africa, plastic waste can be collected either by subsistence waste pickers who sell waste plastic to buy-backs (recycling factories) or municipality workers who deposit the waste material at a landfill station. The sorters at the landfills are trained to sort plastic by visual inspection. The plastic products, which are collected and manually separated include: Polyethylene Terephthalate (PET), High density polyethylene (HDPE), Polyvinyl chloride (PVC), Low density polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and other materials, with international polymer codes 1 to 7 respectively (PlasticsSA 2004).

RDP houses

Proper housing and sanitation is a basic human right, which is recognised by the Constitution and various international human rights instruments (SAHRC 2015). The concept of government subsidy housing commonly known as RDP housing system was established to ensure that the previously disadvantaged groups had well built homes to live in, in order to rectify the injustices of the apartheid era (ANC 1994;Gazette 1994). These low-cost houses are built by the government and given to low income families who cannot afford to build or purchase their own homes. To qualify for a RDP house, one needs to meet the National Subsidy Scheme Criteria (DHS 2019).

The first RDP houses built were typically a two-room brick structure with a corrugated iron roof, had no ceiling and had a pit toilet outside the house. In recent years the housing design has improved. Presently, a typical RDP house has an area of 42 m^2, is made of bricks, has four rooms, namely 2 bedrooms, an indoor bathroom and a kitchen combined with the living room. Some have ceilings and the roof is either made from corrugated iron or clay tiles (Greyling 2009). The average number of people who live in a single RDP house is between 5-10 individuals.

These RDP houses have been of importance, especially for the families who cannot afford to purchase or build their own homes, however there have been several challenges that hinder this social housing initiative from being an absolute success. These challenges include the quality or maintenance of RDP houses (Bailey 2017) and the fact that some RDP recipients sell or rent out their houses to receive an income. The government is under pressure to provide many RDP houses in a short space of time for a growing population (StatSA 2019). This unfortunately leads to questionable quality of the houses in many cases.

1.2 Research objectives

General objective

The main objective of the study is to determine the feasibility of establishing a small WPC business producing building material for low cost housing in South Africa, by utilizing undesirable raw material, such as invasive trees and recycled plastic.

Specific objectives

The specific objectives of this project are to:

- Determine the financial feasibility of producing WPCs made from IAPs and recycled LLDPE plastic for RDP houses.
- Determine the type and costs of the current building materials used and the building standards they need to meet.
- Determine whether there are any standards that the WPCs need to comply with and their advantages over the current building materials. In addition, determine which building structures could potentially be replaced by WPCs.
- Determine whether RDP occupants would accept WPCs in their homes since they are produced from heterogeneous waste materials.

1.3 Method

Study sites

The project focused on the Western Cape to minimize transportation costs. The biomass was sourced from the Berg River area, the recycled plastic was purchased in Bellville and the survey was conducted in the Kayamandi Township under the Stellenbosch municipality.

Data collection

Both primary and secondary data collection techniques were utilized.

- Primary data sources
  Qualitative data was obtained through the use of interviews with key informants (municipality representative, recycling contractor, clearing organisation and building contractors) and questionnaires with RDP occupants.
- Secondary data sources
  The secondary data formed the basis for theoretical and conceptual frameworks of the study. The appropriate literature from previous studies, relevant websites and reports were used.

A set of business assumptions were made in order to carry out the financial analyses for the small hypothetical WPC business. The feasibility of such a business was determined by doing a budgeted statement of profit or loss and comprehensive income to gauge the estimated net profit after tax, break-even analysis to determine the break-even price in order to set a reasonable selling price (SP) per unit, break-even point and value. In addition, net-present value and sensitivity analyses were conducted.

2 Background

The Western Cape Province covers an area of 129 462 km^2 and the 2016 census recorded a population of approximately 6.3 million (StatSA 2016). At the time of writing, the province had an official unemployment rate of 20.4% (StatsSA 2019) and the majority of the working class has no tertiary education and live below the breadline. According to the National Minimum Wage Act there are different minimum wages for different industries. Domestic workers, farm workers, workers hired on an expanded public works programme are entitled to R15, R18, R11 per hour, respectively since the beginning of 2019 (DOL 2018), which translates to a monthly salary of approximately R3 400. It is clear that these people need the government's assistance when it comes to housing and other basic needs.

This chapter will elaborate on the current state of the RDP houses, the type of building material used for construction, the building standards put in place as guidelines for constructing RDP houses and the overall building costs for building one 42 m^2 RDP house.

In addition, it deals with the current global state of plastic recycling, the global consequences of plastic pollution, the driving forces of recycling in South Africa and first world countries, the various recycled polymers, the social and economic benefits of recycling and the general recycling process.

Furthermore, the chapter will elaborate on the issues of IAPs, particularly, the prominent woody trees in the Western Cape. The subsection on the WfW programme will discuss its operations from the year of inception to date and the current uses of the cleared biomass retrieved. Lastly, this chapter will elaborate on how WPCs aim to achieve the objective of producing building material for RDP houses by utilizing cleared IAPs and recycled plastic.

2.1 Current State of RDP houses

The Reconstruction and Development Programme (RDP) is an integrated socio-economic policy framework, which aims at uniting the nation and utilizing its resources to eradicate the results of apartheid (Mandela 1994). One of the five key programmes of the RDP include meeting people's basic needs, under which proper housing falls. To qualify for a RDP house the following National Subsidy Scheme Criteria need to be met: be a South African citizen, earn less than R3 500 monthly, be above twenty one years old, have dependants and not own any other property (DHS 2019).

The R120 000 budgeted for the construction of a single RDP house has remained unchanged for the past six years (DHS 2013). Tenders are given to building contractors and they decide, which building materials to use. The first RDP houses built before the launch of the National Home Builders Registration Council (NHBRC) in 1997 were poorly built houses with an area of 16 m^2 (Greyling 2009). These houses had many problems, such as windows and doors not properly fitted, loose or leaking roofs, visibly cracked walls and poor sanitation. When the NHBRC was introduced, standards and regulations were put into place for the construction of these houses. According to DHS (2010), all houses currently constructed under the National Housing Programme must have a total floor area of at least 40 m^2. In addition, each house currently must have: two bedrooms, an indoor bathroom, a bathtub/shower and washbasin, a combined kitchen and living room and an electricity board if electricity is available in the area.

The South African National Standards (SANS) furthermore provide minimum technical specifications, comprising environmentally efficient design proposals.

2.1.1 Current building materials

The stability and safety of any building are directly dependent on how stable the sub-structure is, specifically the foundation. It is defined as the part of a building, which is in close contact with the soil and intends to transfer the load from the super structure (walls and roof) to the ground without overstressing the soil (SANS10400-H 2012). It provides a level surface, from which to start building. Most RDP houses are built on a strip foundation, which is defined as a continuous strip of concrete intended to distribute the load from the walls evenly to a sufficient area of subsoil (Schmidt *et al*. 2013).

The majority of the houses in South Africa have masonry walls consisting of bricks, concrete blocks or stones in combination with mortar (Schmidt *et al.* 2013). The walls of RDP houses are typically built from concrete blocks and the floors are made from concrete slabs (Figure 1). The masonry walls must have a minimum thickness of 140 mm and the rain penetration acceptance criteria for the category 1 building is that the moisture may not penetrate the wall in an intensity to have it run down the inside walls. The concrete blocks used for constructing RDP houses typically have dimensions of 140 mm x 190 mm x 390 mm (PHP Building Supplies 2017). For any other building category, besides category 1, no obvious wet patches should be on the interior of the wall (SANS10400-K 2015).

Figure 1: A) Concrete blocks used for building the walls and B) the concrete slab used for flooring

When constructing a building, it is mandatory to know the climatic zone you are working in to determine roof and insulation requirements, as these vary based on which zone you are in. Cape Town is in the climatic zone 4 (temperate coastal) and its requirements are different from other climatic zones. Knowing the R-value is essential in keeping a home comfortable all year round. The R-value is the thermal resistance of a component defined as the inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (SANS10400-XA 2011). There are different R-value requirements and they are based on the material used. One roofing requirement is the minimum total R-value given as square metre Kelvin per Watt (m^2K/W), which is the sum of the R-values of the individual component layers in a composite element, including the air space and associated surface resistances. Another requirement is the R-value for roof covering, which is basically the thermal resistance of a component given as (m^2K/W) (SANS10400-XA 2011). Corrugated iron sheet or clay roof tiles are commonly used to assemble the roofs of RDP houses. Presently, the roofs of the RDP houses built in the Kayamandi Township are assembled by using trusses and clay tiles (Figure 2).

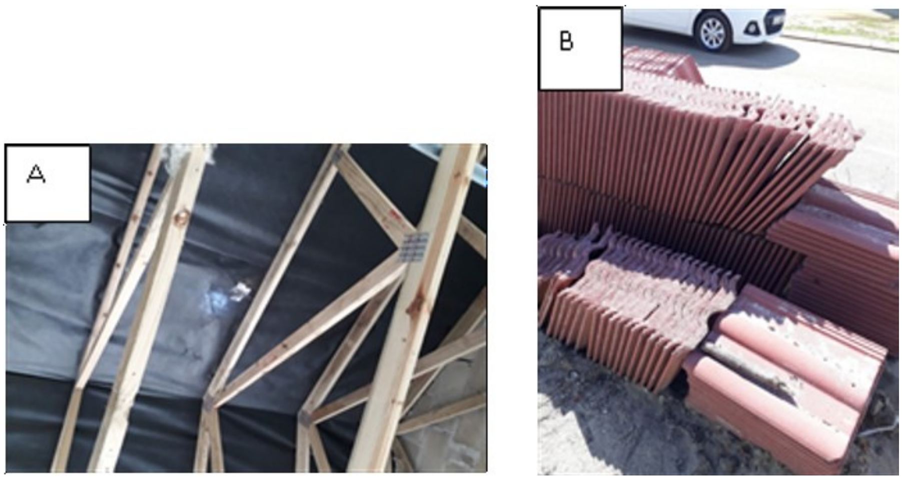

Figure 2: A) Roof trusses and B) clay tiles used for roofing RDP houses

Table 1 lists the properties of materials used to assemble a roof and the insulation requirements in the climatic zone 4. An important value to note is the R-value of 0.05 for the ceiling, which is an important value to consider in the WPC boards intended to replace the current gypsum ceiling boards.

Table 1: The properties of assembling roofs and insulation requirements

Properties	Metal sheeting	Clay sheeting
Minimum required total R-value ($m^2.K/W$)	3.7	
R-value ($m^2.K/W$) of roof covering material	0.30	0.35
R-value of ceiling	0.05	
Added R-value of insulation	3.35	3.30

Previously, RDP houses had no ceilings, however, newly built houses have ceilings installed, which are typically made from gypsum (Figure 3) with dimensions of 3 m x 1.2 m x 0.0064 m. The gypsum, or Rhino board is produced according to the ISO 14001 Environmental Management System and ISO 9001 Quality Management System (Cashbuild 2019). Standard steel windows and doorframes are currently being used with wooden doors. The internal and external walls are plastered and painted, but there is no specific standard for this.

Figure 3: The ceiling in a RDP house

The financial breakdown of the costs to construct a 42 m^2 RDP house was obtained from a building contractor currently building low cost houses in the Western Cape. Table 2 shows the categorized costs, such as foundation, wallplate, roofing, ceiling, plumbing, painting and finishing costs to construct one RDP house. The detailed costs are attached in appendix 1. At the time of writing, the total building material costs were approximately R82 000 and the contractor has a fixed budget of R120 000 per house.

Table 2: The costs of building a RDP house

RDP Building Costs	
Foundation	R13 959.12
Wallplate	R17 169.21
Roofing	R14 735.67
Door and Windows	R4 087.15
Electrical	R1 769.62
Ceiling and additional products	R3 363.30
Plumbing	R3 807.03
Painting and finishing	R2 585.81
Vat	R10 006.77
Total	R81 483.68

2.1.2 Building Standards

The building standard SANS 10400 is used to assist designers and builders to construct structures that fulfil the requirements of the National Building Regulations. According to SANS 10400-A (2010), a RDP house is categorized as a category 1 building in class H3 (domestic residence). These houses have no basements, have a maximum length of 6 meters between connecting walls and a floor area less than 80 m^2.

RDP houses have masonry walls and should have a minimum wall thickness of 140 mm. In addition, the height of the foundation walls should not be higher than 1.5 m and be thinner than the walls which they support. Non-masonry walls in modern houses are not common in South Africa, but wall cladding is slowly becoming popular, especially in malls and some residential homes. Table 3 shows requirements for constructing masonry, non-masonry walls and dry-partitioning.

Any partition or partition wall in any building should have a nominal fire resistance of a minimum of 30 minutes and be non-combustible, or where combustible materials are used, they shall not contribute a load of more than 5 kg/m^2 of floor area in a division (SANS 10400-T 2011).

Table 3: The properties and requirements of the walls

Properties	Masonry	Non-masonry	Dry-partitioning
Thickness (mm)	140(SANS10400-K 2015)		12/12.5 – 15(Schmidt et al. 2013) 14(European Commission 2011) 12(SABISA 2004)
Finished walls thickness (mm)			75 (76), 90(89) or 110(112)(Schmidt et al. 2013) (the real sizes are in the brackets)
Minimum required R-value (m^2.K/W)		1.9(SANS10400-XA 2011)	

As per SANS 10400, the minimum ceiling height above the finished floor level is 2 400 mm in habitable rooms, such as the bathroom, storeroom or pantry (Schmidt *et al.* 2013). The most common materials currently used as ceiling boards are gypsum and tongue-and-groove (T&G) wooden ceilings. Table 4 shows the required properties for ceilings, such as dimensions, strength, water absorption and thermal conductivity. According to Schmidt *et al.* (2013) ceilings have different functions such as:

- It covers the roof construction
- It helps keep out dust
- Provides a fixed place for light fittings
- Can play a key role in the acoustic properties of a room and
- Can contribute to combating the spread of fire in a building.

Table 4: Ceiling properties for gypsum boards, like RhinoBoard (Schmidt *et al.* 2013) and NutecBoard (Everite Building Products 2012)

Properties	**RhinoBoard**	**Nutec Board**
Thickness (mm)	6.4	4 and 6
Width (mm)	900 and 1 200	
Length in 300 mm increments (mm)	2 700 - 4 800	2 400 – 3 600
Mass (kg/m^2)	6	13.0 -37. 0
Minimum MOR (MPa): With grain Minimum MOR (MPa): Across grain		7.40 10.60
Target density (g/m^3)		1.26
Thermal conductivity (W/m.K)		0.19
Moisture content (%)		6.25
Water absorption (%)		37.72

The standard SANS 10103 (2008) recommends acoustic insulation properties, which are listed in Table 5 as the maximum noise levels acceptable for a household.

Table 5: Maximum noise levels for different rooms in a household (SANS 10103 2008)

Types of occupancy or activity	**Maximum equivalent continuous rating level ($L_{Req,T}$)a for ambient noise dB(A)**
Living rooms	45
Kitchens and service areas	55
Bathrooms and toilets	55
Bedrooms	40
General house rooms(Schmidt *et al*. 2013):	38-39

2.2 Current state of recycling

The growing population, rapid urbanization, thriving economy and the increase in living standards have considerably accelerated the generation of plastic waste globally. In South Africa the urbanisation rate has increased from 60% to over 65% between 2007 and 2017 (Statista 2018). Plastic is an indispensable part of our lives and utilized in a multitude of applications, however, plastic waste has turned into one of the major global environmental issues. An initiative trying to address these issues is the development of a “Green Economy” (DEA 2019c).

South Africa interprets green economy as a sustainable development path based on addressing the interdependence between economic growth, social protection and natural ecosystems. The green economy refers to two inter-linked developmental outcomes for the South African economy (DEA 2019c):

- Growing economic activity (which leads to investment and job creation) in the green industry sector.
- A shift in the economy as a whole towards cleaner industries and sectors.

The green economy is categorized into eight sectors, whereby sustainable waste management is one of them (DEA 2019c) and is of concern particularly in this project. Sustainable waste management has great potential to create employment opportunities and minimize the single use of plastic. Recycling of plastic waste is considered sustainable in manufacturing new products, such as being incorporated with suitable biomass to produce WPCs, because waste plastic is used instead of virgin plastic, thus contributing to sustainable development.

2.2.1 The scale of the problem

Creation of waste lessens natural resources, uses water and energy, places pressure on land, causes pollution and creates extra economic cost for its management (Song Li and Zeng 2015). The entire world is challenged with escalating amounts of waste and its environmental consequences. For over 60 years global plastic production has continued to increase at an exponential rate since 1950. Plastic production in the 1950s was estimated to be 2 million tonnes and it rapidly grew to over 300 million tonnes in 2015. Over this period, the cumulative production reached over 8 billion tonnes (Ritchie 2018). Plastic materials are currently among the most popular and essential materials utilized in the modern world. They are used in a whole range of products, such as food and non-food packaging, consumer goods, automotive and construction. Plastic use in the automotive industry for instance has increased in order to manufacture cars more energy efficient and lightweight (Goodship 2007).

According to Geyer *et al*. (2017), Ritchie (2018) and Amos (2017), approximately 8.3 billion tonnes of virgin plastic have been produced globally and presently over 300 million tonnes of plastic are produced annually, but the majority is discarded after a single-use (Schnurr *et al.* 2018). According to Amos (2017) roughly half of the virgin plastic produced was made in the past 15 years and approximately 30% of the historic production remains in use today. Of the 6.3 billion tonnes discarded plastic waste (Mortillaro 2017), about 9% has been recycled, 79% accumulated in the environment or landfills and 12% incinerated (Geyer *et al*. 2017). If the current production and waste management trends continue and do not change for the better, current trends point to 12 billion tonnes of waste by 2050 (Amos 2017) on a global scale.

Plastic packaging is responsible for the largest part of plastic use, yet it has a short lifespan designed for immediate disposal (Giacovelli 2018). Plastic packaging represents 26% of the total global volume of plastic used (MacArthur 2017), followed by the construction and automotive industries (Gourmelon 2015, PlasticSA 2018). The plastic consumption in South Africa for 2018 was 1.88 million tonnes and 352 000 tonnes recycled into raw material. This resulted to a recycling rate of 46.3%, which is well-above that of 31.1% in Europe (PlasticsSA 2019).

China is the biggest plastic producer, followed by Europe. Globally, plastic waste is accidentally transferred as macroplastic and microplastic via rivers, wind or poor waste management into the sea. Macroplastic is visible plastic that can be collected easily (>5 mm), and microplastic refers to small particles with a diameter below 5 mm (Schnurr *et al*. 2018).

South Africans use a lot of single-use plastic most common in the beverage and food industries, such as straws, coffee cups and plastic bags, which may be considered the main reason for increasing levels of plastic pollution (PlasticsSA 2019). 94% of the litter on beaches in South Africa is plastic, with 77% of that being single-use. They are highly prone to littering since they are easily blown away by wind and rain (WWF 2018) and poor waste management. Responsible waste management is vital in ensuring the sustainability of our planet. The City of Cape Town currently has 24 public waste drop off sites established for disposing small loads of non-domestic waste, such as garage waste, clean garden waste etc. Domestic waste is deposited into landfills or transported to recycling centres (City of Cape Town 2018).

2.2.2 Consequences of plastic pollution

Plastic in the environment poses major hazards to wildlife, both in the ocean and on land. This is a global emergency, because most plastic is not biodegradable and remains in the environment for hundreds of years (Bashir 2013). Current assessments report that there is an estimated 150 million tonnes of plastic in the ocean today. Plastic material, especially plastic bags, have been retrieved from the stomach and breathing passages of different animal species, which mistook the plastic for food. There is emerging evidence that the toxic chemicals added during the manufacturing process transfer from the consumed plastic into the animals' tissue, eventually enter the human food chain. When plastic breaks down into microplastic particles, it becomes even more problematic to detect and to remove from the environment (Giacovelli 2018).

Therefore, recycling plastic is important, since it protects the environment (Conserve Energy Future 2019a and Mamphitha 2012) by:

- Minimizing the use of raw materials
- Reduces the impact of landfill on the environment
- Decreasing litter, especially in pristine and living environments.

2.2.3 Waste collection services

Social, economic and environmental factors are the three basic drivers influencing solid waste recycling management at household level. Recycling in South Africa is based on economic principles, which means that people recycle to get monetary benefits, whereas in Europe recycling is based on an environmental principle, to which most citizens subscribe. Manual labour is used to collect, sort and recycle waste in South Africa, whereas in Europe the entire recycling process has become automated and mechanised (PlasticSA 2018).

When comparing three residential areas in South Africa – urban areas, townships and rural areas – it is clear that the municipal services rendered differ immensely and are not provided in an equal manner. Waste management services are often limited to urban areas and a few townships (Ntanjana 2018) resulting to 34% of South Africans not having access to waste management services (PlasticsSA 2019). In rural areas, there are typically minimum to no recycling services offered by the municipality. Thus, residents dispose their own waste either at a communal dumping site or privately behind their houses. Most people living in affluent urban areas are environmentally cautious and understand the importance of recycling and separate their waste without expecting any financial incentive or compensation. In most townships, however, the residents are not environmentally conscious or understand the consequences of pollution. However, they collect, separate and recycle waste in order to get financial compensation from buy backs (Meincken *et al.* 2018). According to StatsSA (2017) a report on General Household Survey for years 2002-2016 confirmed that waste recycling is most common in provinces with large urban populations, such as Western Cape and Gauteng and least common in most rural provinces, such as Limpopo.

The Waste-to-energy (WTE) technology implemented in some developed countries with the aim to use municipal solid waste to generate energy (Dlamini *et al.* 2018) proves to be an excellent initiative, considering that there is little available land for landfilling nowadays and the high urbanization rate. In developed countries such as Germany, in Hamburg particularly, municipal waste collection services are advanced. The only informal waste pickers are those who collect glass bottles and plastic bottles to get an incentive at grocery shops. If waste is unrecyclable, it is not deposited in landfills like in South Africa, but rather it is incinerated for heat and electricity (MVB 2008) which are supplied to households.

2.2.4 Recycled polymers

Plastic is made from low molecular weight monomers, organic materials, which are mostly obtained from petroleum that are fused together by a process called “polymerization” (Bashir 2013). According to Biron (2013) there are two categories of plastic namely, thermoplastic and thermosets. Thermosets are a group of plastic that go through chemical transformation when heated, creating a three-dimensional network, which cannot be re-melted and reformed making it difficult for them to be recycled.

Thermoplastics are a group of plastic that can be reheated, reshaped and cooled repeatedly, such as Polyethylene Terephthalate (PET), High density polyethylene (HDPE), Polyvinyl chloride (PVC), Low density polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and other materials. Their common uses and what they are recycled into is shown in Table 6. The plastic considered in this study is LLDPE.

Table 6: Plastic identification code and common uses adapted from Plastic New Zealand (2009) and PlasticSA (2004)

The Plastic Identification Code

Symbol	Plastic Type	Properties	Common Uses	Recycled into
1 PET	PET Polyethylene Terephthalate	Clear, tough, solvent resistant, barrier to gas and moisture, soften at 80°	Soft drink and water bottles, salad domes, biscuit trays, salad dressing and containers	Pillow and sleeping bag filling, clothing, soft drink bottles, carpeting, building insulation
2 HDPE	HDPE High Density Polyethylene	Hard to semi-flexible, resistant to chemicals and moisture, waxy surface, opaque, soften at 75°C, easily coloured, processed and formed.	Shopping bags, freezer bags, milk bottles, ice cream containers, juice bottles, shampoo, chemical and detergent bottles, buckets, rigid agricultural pipe, crates	Recycling bins, compost bins, buckets, detergent containers, posts, fencing, pipes, plastic timber
3 PVC	PVC Unplasticised Polyvinyl Chloride PVC-U Plasticised Polyvinyl Chloride PVC-P	Strong, tough can be clear, can be solvent welded, softens at 80° Flexible, clear, elastic, can be solvent welded.	Cosmetic containers, electrical conduit, plumbing pipes and fittings, blister packs, wall cladding, roof sheeting, bottles Garden hose, shoe soles, cable sheathing, blood bags and tubing	Flooring, film and sheets, cables, speed bumps, packaging, binders, mud flaps and mats, new gumboots and shoes
4 LDPE	LDPE Low density Polyethylene	Soft, flexible, waxy surface, translucent, softens at 70°C, scratches easily.	Cling wrap, garbage bags, squeeze bottles, irrigation tubing, mulch film, refuse bags	Bin liners, pallet sheets
5 PP	PP Polypropylene	Hard but still flexible, waxy surface, softens at 140°C, translucent, withstands solvents, versatile	Bottles and ice cream tubs, potato chip bags, straws, microwave dishes, kettles, garden furniture, lunch boxes, packaging tape	Pegs, bins, pipes, pallet sheets, oil funnels, car battery cases, trays
6 PS PS-E	PS Polystyrene PS-E Expanded polystyrene	Clear, glassy, rigid, opaque, semi-tough, softens at 95°C. Affected by fat, acids and solvents, but resistant to alkalis, salt solutions. Low water absorption, when	CD cases, plastic cutlery, imitation glassware, low cost brittle toys, video cases\ Foamed polystyrene cups, takeaway clamshells, foamed meat trays, protective packaging and	Coat hangers, coasters, white ware components, stationery trays and accessories, picture

		not pigmented is clear, is odour and taste free. Special types of PS are available for special applications.	building and food insulation	frames, seed trays, building products
Other Packaging	Other packaging In packaging, it could be multi-layer materials e.g PE+PP	Includes all resins and multimaterials (e.g. laminates). Properties dependent on plastic or combination of plastics.	Automotive and appliance components, computers, electronics, cooler bottles, packaging	Plastic timber, sleepers – looks like wood, used for beach walkways, benches etc.

According to PlasticsSA (2019), LDPE and LLDPE packaging films are the most widely recycled material (34%), followed by PET (21%), HDPE and PP (18% each) PVC (6%) and PS (2%). Apart from recycling plastic waste, many governments all over the world aim to ban single use plastic bags or implement levies on their use (Xanthos and Walker 2017). In 2003 the South African government introduced legislation intended to reduce plastic bag litter by charging consumers a fee to purchase shopping carrier bags (Hasson *et al.* 2007). There was an initial short-term drop in plastic bag utilization, followed by a steady increase in demand illustrating that the policy has partially failed. Consumer behaviour has not changed because people have become accustomed to paying for plastic bags and the levy is too small (Dikgang *et al.* 2010).

2.2.5 Job creation

Apart from the environmental benefits of responsible waste management, recycling creates both formal and informal employment for people. There is an interdependency between waste generating areas, such as shopping malls, factories and households, subsistence waste collectors and buy-back centres (recycling factories). According to Langenhoven and Dyssel (2007), the Department of Environmental Affairs (DEA) in South Africa acknowledged in 1998 that recycling could better the livelihoods of impoverished individuals and launched a campaign encouraging entrepreneurs to establish "buy-back" centres. These are privately owned businesses, which are often located in low-income areas or industrial areas and they recycle plastic waste.

Apart from their contribution to an increased recycling rate, buy-back centres have job creating roles at three different levels (Viljoen *et al*. 2017). The first tier includes the entrepreneur who establishes, operates and manages the buy-back centre, followed by the sorters and balers who accept the recyclables from the third tier which are the informal waste collectors. The buy-backs play a fundamental role in facilitating the recycling potential of informal sector participants by compensating collectors for delivering certain types and grades of recyclables to them for recycling.

Waste pickers collect roughly 80-90% post-consumer packaging and paper that is recycled and save municipalities approximately R750 million in landfill space annually (DEA 2019d). In 2018 the plastic recycling industry created 7 832 formal jobs in recycling factories and 58 470 through informal jobs, such as waste pickers and collectors who provided recyclable materials to buy backs. The recyclable material contributed an estimated amount of R2 267 million into the economy at primary sourcing level, that being material purchased from informal waste collectors and waste management companies (PlasticsSA 2019).

Another way people are encouraged to recycle is without monetary incentive, which involves giving them items they may need in their households or their everyday lives. The Stellenbosch Municipality started an initiative to encourage recycling in the townships in 2016 through a campaign called “Swop Shop”, which is a mobile shop stocked up with basic needs, such as fruit, soap, coffee, tea, sugar, stationery, clothes and shoes. Items, such as clothes and shoes are donated by the general public or municipal staff. The project allows the municipality to make a positive socio-economic investment in the communities and demonstrate how beneficial mutual cooperation is (Stellenbosch Municipality 2016).

Residents bring their sorted recyclables to the swop shop in standard size clear plastic bags, which are given to them by the municipal representatives at the swop shop. One bag of plastic, cardboard or paper recyclables is worth one coupon and a bag of glass or cans are worth three coupons. As residents trade in their bags, they are issued with coupons, which they then use to trade for the goods in the mobile swop shop. The store operates in the different townships on different times and days. During the day, they attend to the adults and after school they attend to the pupils (Stellenbosch Municipality 2016).

2.2.6 Recycling process

The recycling industry is classified into two tiers. The first tier is an intermediate market that comprises of collectors, processors, converters and processors. Some of the recycling companies have their own transport to collect waste around the Peninsula. The second tier is the end-use market that utilizes recovered material to manufacture new products, such as wood plastic composite products and non-food packaging plastic (Langenhoven and Dyssel 2007).

As discussed during a personal interview, the recycling factories pay for recyclables based on type, grade and weight. The plastic is sorted based on its polymer code and ranked into three quality grades - A, B, C - in descending order. A-grade plastic is clean material generally sourced from shopping centres and recycled into pellets used for non-food packaging, such as refuse bags, furniture coverings, etc. C-grade is contaminated plastic that is converted into conglomerates, which resembles coarse, irregular shaped granules. It is used for the production of wood plastic composite materials, since it is the cheapest material available and has the ability to be heated and shaped to almost any form to produce other objects of practical value.

The recycling interviewee further explained that the recycling process depends on various factors, such as the quality, ease to recycle and the end-market after conversion. Waste collectors are paid approximately R1 200–R9 000/t depending on the grade. Plastic packaging from shopping centres is either collected by trucks from the recycling factories or individual collectors, who sell to the factories. The collectors inspect the different plastic products visually and sort by hand. Once delivered to the recycling centres, the workers sort the plastic waste further, into different grades (A, B, C). The plastic of interest in this project is LLDPE which originates mainly from shopping bags and cling wrap converted into conglomerates.

2.2.6.1 The flow of recyclables

Plastic recycling is turning waste plastic into forms of new plastic material by going through the following steps (Rosato *et al.* 2014):

1. Collection: Plastic waste is collected from various shopping centres, factories, households and retailers by either the municipality waste collectors, or self-employed collectors.
2. Sorting: The plastic is separated visually into different polymer codes (Figure 4), based on product and colour, such as bottles, plastic sheeting etc.

Figure 4: Plastic pre-sorting at the landfill

3. Compression: The recyclable material is compressed, baled and transported to the recycling factories (Figure 5)

Figure 5: Compressed and sorted material received at the recycling plants

4. Washing: At the buy-back, the plastic can be sorted further then followed by washing. Plastic is washed to remove adhesives, paper labels and other contaminants (such as food etc.) and air-dried. Some buy-back centres recycle their own polluted water and reuse it or use rain water.

5. Size reduction: The sorted and washed plastic is comminuted in one of the following ways:

    - Cutting is carried out for initial size reduction of large items. It can be done with scissors, shears or saws.

    - Shredding is suitable for smaller pieces. A typical shredder has a series of rotating blades. The product is a pile of coarse irregularly shaped plastic flakes (Figure 6), which can be processed further.

Figure 6: Shredded plastic flakes

    - Agglomeration is the process of pre-plasticising soft plastic by heating, rapid cooling to solidify the material and finally cutting into small pieces. This is often carried out in a single machine. The products are coarse granules called conglomerates (Figure 7).

Figure 7: Conglomerates made from grade C LDPE

- Further processing- In order to produce pellets, the plastic is fed into an extruder, where it is melted and extruded through a multi-hole die in the form of continuous strings, which are cut into pellets by a revolving cutter (Figure 8).

Figure 8: Pellets made from grade A LDPE

There is a wide range of products that can be produced from recycled plastic. However, the market for recycled plastic is restricted due to the variation in the raw material. Some manufacturers incorporate small amounts of well-sorted recycled material into their products, while others may incorporate larger quantities, depending on the quality required. The range of products made from recycled plastic includes packaging for non-food items, building materials (WPCs), shoe soles, toys, office equipment and many more (PlasticSA 2017).

2.3 Invasive trees in Western Cape

2.3.1 Current situation in Western Cape

South Africa's indigenous vegetation is diverse, and divided into nine biomes (Figure 9). Each biome is categorized by particular fire and rainfall regimes, levels of agricultural and human use and tend to be invaded by unique suites of IAPs (Mucina and Rutherford 2006). Of the 9 000 plants introduced to the country, 198 are currently categorized as being invasive (DEA 2019a). The project will focus on woody IAPs from the fynbos biome found in the Western Cape.

There is an increasing global concern about the impact of IAPs. Historically, the concern was predominantly about the impact on human society, such as the decrease in agricultural production, but currently there is growing recognition of the impact on biodiversity and natural systems. Alien plants, especially trees and woody shrubs, have invaded over 10 million ha of South Africa (Meijninger and Jarmain 2014) with the Western Cape being the most heavily invaded at about a third of the total area (Richardson and Wilgen 2004). The Berg and Breede Rivers in Western Cape are the most heavily invaded catchments, followed by the George-Tsitsikamma region, the Port Elizabeth coastal region and the Drakensberg escarpment in Mpumalanga (Le Maitre *et al.* 2000).

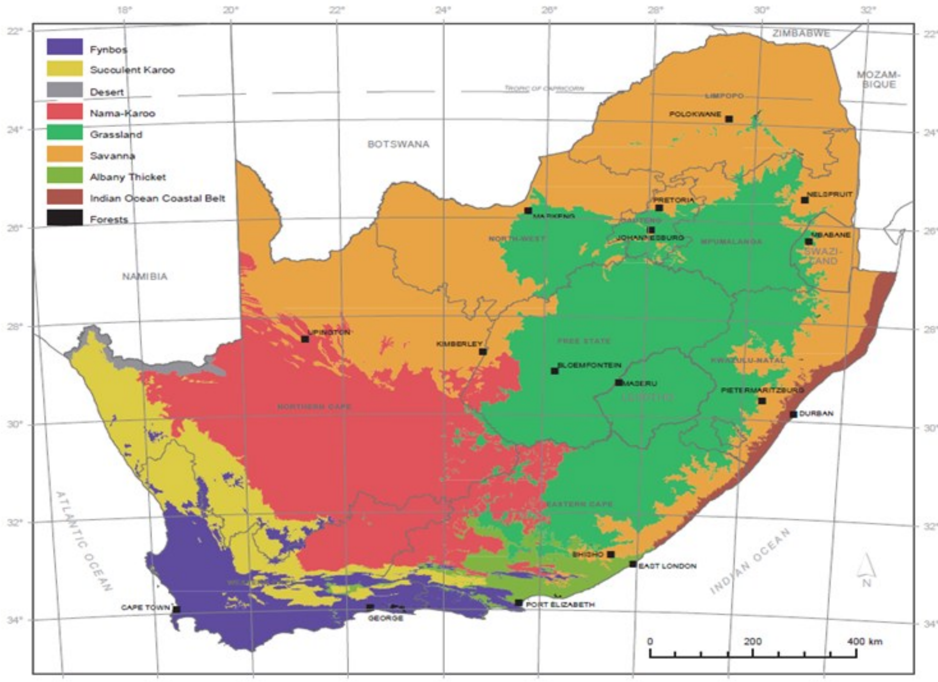

Figure 9: Map of the biomes in South Africa (Mucina and Rutherford 2006).

The fynbos biome situated in the Western Cape is dominated by fire-prone, Mediterranean-climate shrublands. This region receives winter rainfall and plants experience drought stress during hot, arid summers (Dallas and Rivers-Moore 2014). Many plants in the biome need regular fire to propagate hence, prescribed burning has been regarded as an essential management practice in fynbos ecosystems for over 50 years (Van Wilgen 2009).

2.3.2 Prominent invaders

The most prominent woody invaders are in the genera *Pinus* (pines), *Acacia* (wattles) , *Hakea* (shrubs in the family Proteaceae) and *Eucalyptus (*gums), particularly *Eucalyptus camaldulensis* (Brown *et al.* 2004, Kotzé *et al*. 2012, Van Wilgen 2009). The main riparian invader is *Acacia mearnsii*, which tends to form dense stands that displace the indigenous fynbos and forest vegetation (Brown *et al.* 2004). Invasive trees have different characteristics, thereby affecting ecosystems differently.

Fire is the primary driving force, especially for propagation of indigenous fynbos in the ecological dynamics of fynbos ecosystems, and these veld fires are essential and inevitable. The invasion by fire-adapted IAPs is arguably the biggest threat to the fynbos ecosystem, since they thrive after a fire (Van Wilgen 2013). Some IAPs regenerate profusely after a veld fire, either because the heat breaks open the serotinous fruits and cones (*Hakea* and *Pinus*), releasing the seeds or the heat stimulates germination (*Acacia*) (Taylor 1969).

The seeds are winged and have the ability to spread over great distances after fires. Wattles also produce copious amounts of seeds, however, they are only released on ripening. Wattle seeds are hard-coated and accumulate in the soil and are spread by humans or animals when soil is transported, or carried downstream in rivers, which increases new establishments along rivers or streams and germination is stimulated by veld fires (Van Wilgen 2013).

A. mearnsii is presently considered as one of the most aggressive plant invaders in Western Cape and is classified as a transformer species (Holmes *et al.* 2005). This is due to the fact that many problems are linked with condensed stands of *A. mearnsii*, such as an increase in riverbank erosion, an increase in the fuel load and a reduction in species richness. Most IAPs, including *A. mearnsii,* consume large amounts of water compared to the indigenous fynbos vegetation, with runoff from infested catchments being between 30-70% less than the uninvaded fynbos. *A. mearnsii* is difficult to control since it coppices easily after felling and burning (Brown *et al*. 2004). Another aggressive invasive tree in Western Cape is *Acacia saligna,* because it has high growth rates, resulting in taller vegetation than indigenous fynbos shrubs, it has the ability to resprout and thrive after fires and it can fix nitrogen into the soil. These characteristics mean that *A. saligna* has long-lasting effect on the environment as opposed to other invasive trees, which cannot resprout after fires or fix nitrogen (Mostert *et al.* 2017).

2.3.3 Working for Water Programme

According to DWAF (1998), the National Water Act recognises water as a scare natural resource belonging to all people and water protection is necessary to ensure sustainable supply to all consumers. Therefore, effective management and proper maintenance of the nation's water supply is imperative. In order to eradicate problems caused by IAPs the government launched the Working for Water (WfW) programme in 1995/1996 to reduce IAPs and create jobs (Kotzé *et al.* 2012). The programme has created employment for approximately 30 000 people annually and cleared over 2.1 million ha of IAPs (Hoy *et al*. 2014).

The WfW programme is a pioneering environmental initiative in that its implementation successfully pools ecological concerns and social development, which had an initial grant of R25 million from the (then) Reconstruction and Development Programme Fund (O'Donoghue and Fox 2009). The main objective of WfW was and still is to eradicate IAPs from river systems, mountain catchments and other natural areas to enhance runoff, conserve biodiversity and restore the land (Marais and Turpie 2001). Although the initial emphasis of WfW was on water conservation and the environment, it has made a significant contribution to the welfare of it labourers and families, who are often from disadvantaged communities.

As the programme expanded, its social focus developed, thus obtaining additional funding mostly from the government's poverty relief budget, since it had proven its substantial employment potential (Magadlela and Mdzeke 2004). By 2005 the WfW budget had increased to over R400 million (Hoy *et al.* 2014) and in the 2019/2020 budget, R30.7 billion was set aside for Agriculture and Rural Development, of which the WfW programme forms part (National Treasury 2019).

To determine whether the WfW programme was effective, the National Invasive Alien Plant Survey was initiated and implemented by the Agricultural Research Council. Its aim was to form and implement a low-cost and statistically sound IAP monitoring system for South Africa, Swaziland and Lesotho at quaternary catchment level (Kotzé *et al.* 2010). The clearing of IAPs along the catchment is a standard technique done by various contractors using chemical, mechanical, biological or integrated control methods (DEA 2019a). The operations are funded by the WfW programme through the DEA. According to Mudavanhu *et al.* (2017), over 19 000 contracts have been signed for clearing operations between 2008-2014.

Large sums of money have been invested (presently R1.5 billion annually) into this programme since its inception (van Wilgen and Wilson 2018), hence it is essential to introduce ways to obtain economic benefits, other than just ecological benefits. The value added industries (VAI) project was initiated under the WfW programme to develop additional benefits of extracting IAPs. This project aims to:

- Minimize the overall costs of clearing IAPs
- Increase economic impact by starting wood product businesses that can use IAPs and create jobs
- Reducing potential negative environmental impact, such as fire damage, by leaving a small proportion of biomass after clearing has occurred (DEA 2019b).

The existing VAI projects from other provinces produce the following products (DEA 2019b; Mander 2017): charcoal, firewood and woodchips, screen and blinds, wooden educational toys, decoration items for homes/lifestyle shops, fencing and garden furnishings, bathroom accessories, indoor and outdoor furniture and lamps.

2.3.4 Current uses for invasive trees cleared along the Berg River

The Berg River Catchment was selected as the study area (Figure 10), considering that it is one of the most invaded catchments. It originates in the Franschoek and Drakenstein mountains and flows northwards past Paarl, Wellington, Hermon and Gouda where it is joined by the Klein Berg and Vier-en-Twintig rivers. The Berg River then flows westwards past Porterville, Piketberg, Hopefield and Velddrif to discharge into St. Helena Bay on the west coast. The rainfall occurs predominantly in winter and differs from less than 300 mm/year at the coast to 3 200 mm/year in the mountainous south (McLean 2018). It is roughly 294 km long from the source to mouth with a catchment area of 7 715 km^2 and the riparian habitats along its banks are dominated by IAPs (Tererai *et al.* 2013).

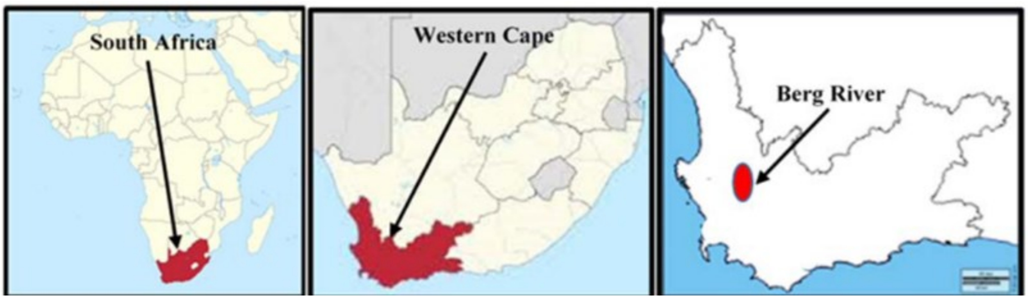

Figure 10: Map showing the Berg River catchment in the Western Cape (Mudavanhu *et al.* 2017)

This project proposes to utilize the woody biomass sourced from clearing operations along the Berg River to produce WPCs. At the time of writing, the cleared biomass was either collected by local people for firewood or left to decompose.

2.4 Wood Plastic Composites

The rising concern towards environmental issues has led to increasing interest in polymer composites (La Mantia and Morreale 2011), of which WPCs form part of. The study will utilize the IAPs which pose as an environmental threat and recycled LLDPE plastic to produce potential building material, which can be in the construction of RDP houses. Plant fibres are generally suitable to reinforce plastic due to relative high stiffness and strength, low cost, low density and they have low carbon-dioxide emission (Ashori 2008). WPCs are used in a variety of applications, construction and automotive applications being the most common worldwide (La Mantia and Morreale 2011).

In a South African context, the WPC industry is a relatively young one and only two companies produce their products locally with the main focus on decking, cladding and outdoor furniture (de Kock 2017). This opens an opportunity for other structures to be manufactured, such as ceiling boards, which are proposed for this project. The decision to use WPC products as an alternative should be based on achieving better performance, decreased price or reduced environmental impact (Schwarzkopf and Burnard 2016). The WPC properties, suitability and financial analysis discussed in the relevant chapters will determine the viability of this proposed material as an alternative to the current building materials utilized for RDP house construction.

3 Survey in Kayamandi

In this section housing problems experienced by some RDP occupants and their views on WPCs as a building material are discussed. Door-to door questionnaires were conducted and the results of the questionnaires are presented.

3.1 Description of study area

The study was conducted in the Kayamandi Township located in the Stellenbosch Municipality (Figure 11). Kayamandi has an area of 154 ha, a total population of 24 645 with approximately 9 000 households. Kayamandi has a dependency ratio of 39.9 (StatsSA 2011). The dependency ratio is defined by the number of dependents aged between 0-14 and over 65 to the number of people in the working group. It highlights the number of employable people compared to the number of unemployable people (Kenton 2019), calculated as 100 * (number of dependents / number of employable age). The township has a housing ownership percentage of 25.11% (StatsSA 2011). Social housing remains a challenge due to limited financial resources, growing population and scarce land for construction.

Figure 11: Kayamandi Township in Stellenbosch Municipality. Map adapted from Google Maps (2019)

Kayamandi has both shacks made from corrugated iron sheets and masonry houses (Figure 12). Most of the people living in shacks have no running water and sanitation services in their houses, but there are community taps and toilets available. Many people apply for RDP houses and the demand for proper housing continues to grow annually due to the growing population. This makes it very difficult for government to meet people’s needs since there are many constraints (financially and land).

Figure 12: An example of masonry houses and shacks in Kayamandi, image adapted from Charles (2019)

3.2 Sample selection

A Stellenbosch representative assisted in identifying two sample communities with old constructed RDP houses and newly built houses. Since the focus was on determining the condition of the newly built RDP houses, only residents who lived in such houses were approached for the main data collection. According to Swanepoel (1995), the randomness of a sample is more important than its size. This justifies the use of a sample size of 34 households in a total population of 241 homes, which were randomly selected in Kayamandi, each house representing one respondent. The sample size was constrained by the limited numbers of newly built RDP houses, the unwillingness to participate, or unavailability of respondents. At the time of writing 241 newly built houses existed, which means that 14% of the newly built RDP houses were approached for the survey. The survey began at a random house with no prediction of the next house to approach, thus walking from one house to another. This random selection gives equal chances for other participants to be included in the project and eliminates any systematic bias (Sinclair 1975).

Approaching local people to participate during a survey is beneficial because they know their circumstances and surroundings best. In addition, local people know the sources of information better than outsiders. Having a local person accompany the interviewer during data collection eased the respondents suspicions and they became more willing to participate (Swanepoel 1995).

3.3 Pre-testing

Designing a perfect questionnaire is almost impossible. However, effective questionnaires can be created. In order to evaluate the usefulness of a questionnaire, it is important to pre-test it before conducting a survey. Pre-testing can help identify problems concerning order, wording or question formatting (van Teijlingen and Hundley 2002), which might hinder participants from giving relevant answers or hinder them from participating. Pre-testing is a way of checking whether questions are clear and can be comprehended by the respondents (Hilton 2017). Thus, pretesting was conducted prior to the actual field work in eight households. The participants who took part in the pre-test did not participate in the main data collection to avoid repetition. After the trial run, vague questions were rephrased or removed. Open spaces were left for additional comments or information.

3.4 Data collection

Data sources can be divided between primary source, which is the raw data collected and produced by a researcher and secondary source, which is the data that has already been collected by other people (Ajayi 2017). Data can either be qualitative, meaning it is non-statistical and it is usually in a form of questionnaires, interviews, observations, or quantitative meaning it is measured using numbers, which come in a form of experiments and tests (Pickell 2019).

The main way of collecting data in this study was through door to door questionnaires, which was approved by the university's ethical clearance department. The field work was conducted in September 2018.

3.4.1 Questionnaires and interviews

Personal questionnaires were selected as the most suitable and easiest way of collecting data from the RDP occupants. It was expected that some participants might be uneducated, and that the interviewer would have to explain what the project was about, ask and explain the questions, interpret the feedback and help record the answers for participants. The survey followed a semi-structured interview format, which is often used in qualitative research, which remains one of the best ways to collect data and gain perspective (Swanepoel 1995). The questionnaire had a combination of open and closed-ended questions (appendix 2). The open-ended questions allowed the participants to express their views and give the interviewer additional information (Torkar *et al.* 2011). The questionnaires were structured around the following main sections:

- Number of people staying in each house

- Number of years occupants have lived in the house
- What infrastructure problems are experienced in houses
- Solutions to problems
- If they are open to the idea of WPCs and would they purchase a product made from this material.

The choice in language has an influence on the way people respond to the questions (Harzing 2004), hence in participatory rural research it is imperative to understand the local language to accommodate those that are neither learned nor English speaking. The interviewer was accompanied by a local person who spoke isiXhosa fluently, thus no one was excluded. Utilizing an interpreter who has good knowledge of both languages (isiXhosa and English) and no bias was essential in order to obtain accurate responses (Swanepoel 1995). The aim of the study was explained and the RDP occupants had an option to participate in the study or not. If they refused, the next house was approached.

3.4.2 Transect walks and observations

According to Keller (2019) a transect walk is an organized walk across the community with the local people to explore and observe the surroundings. This involved walking around the Kayamandi township with a community member, observing the infrastructure, asking questions, listening and making notes of those observations (Swanepoel 1997). These personal walks and observations were useful in identifying observable infrastructure defects and the housing situation in the area and to add information to the questionnaires.

3.4.3 Questionnaire analysis and interpretation

Microsoft Excel was utilized to convert and interpret the raw data from the questionnaires. Descriptive statistics was used to discuss the results in detail. Tables and pie charts were used for visual presentation and explanation of the data analysis.

3.5 Research results

The 34 respondents living in the newly built single storey houses (Figure 13) were expressed as percentages and each respondent represented a household. The results obtained in the Kayamandi Township through observations, transect walks and questionnaires were as follows:

Figure 13: Newly built RDP houses in Kayamandi

Most of these houses have running water and electricity, they are made from concrete blocks but are clustered together, which tends to be problematic in cases of fires. These 42 m^2 houses often have to accommodate large families. Figure 14 shows the number of people living in one RDP house, a majority (35%) having five family members per house, followed by six to ten family members (32%). It is worth mentioning that most of the people living in these RDP houses live off the government's assistance through social grants intended for the elders and young children.

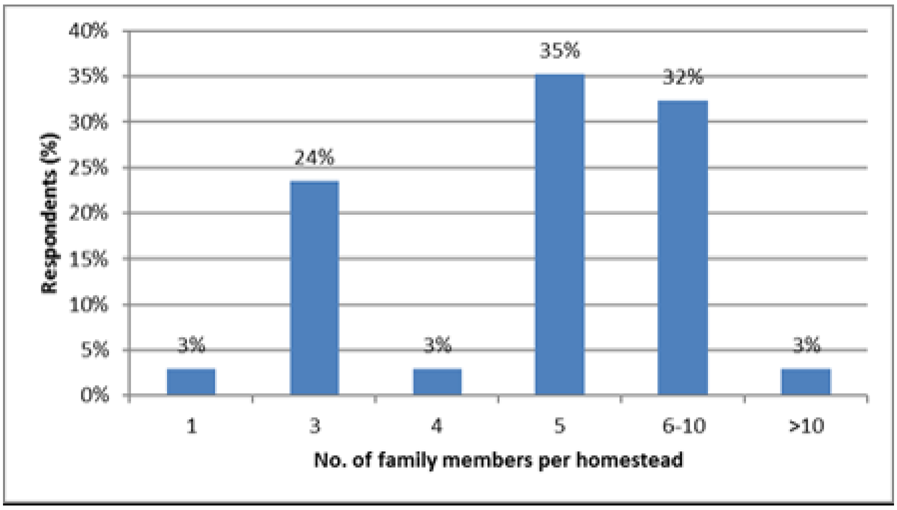

Figure 14: Number of family members per homestead (n=34 respondents)

Since most of the data collection was done on the newly built houses, the occupants were asked how long they have lived in their houses. A large majority of the respondents (73%) have lived in their new houses for two years (Figure 15). The state of the houses, however, does not reflect the number of occupancy years

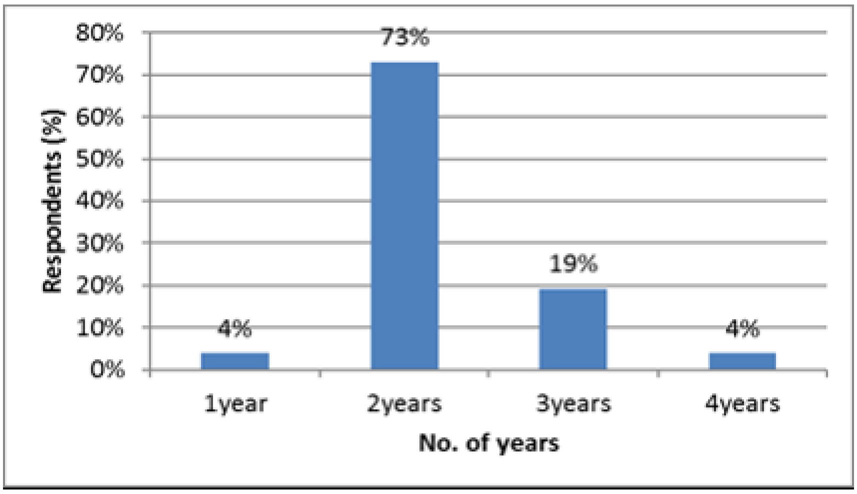

Figure 15: Number of years respondents have lived in their RDP homes (n= 34 respondents)

The exterior of the newly built RDP houses look decent, however the interior have several problems. The respondents were asked about the most common problems they experience in their houses. 33% of the respondents complained about poor sound insulation, meaning they hear sounds from other rooms, even when the sounds are not loud, 33% also complained about poor thermal insulation, 26% complained about thin walls and 8% complained about leaking roofs (Figure 16). Observations showed that most of the houses had cracked walls and the most alarming defect were mouldy interior walls. The residents complained that when it rains the walls absorb rain water resulting in swollen walls and leaving damp patches, which result in the walls becoming mouldy. Most respondents (86%) complained about mouldy walls in the open-ended question. Some older houses do not have ceilings. Only 14% participants living in houses with ceilings mentioned that the ceiling boards were cracked and not stable enough and when they close doors the ceiling boards wiggle.

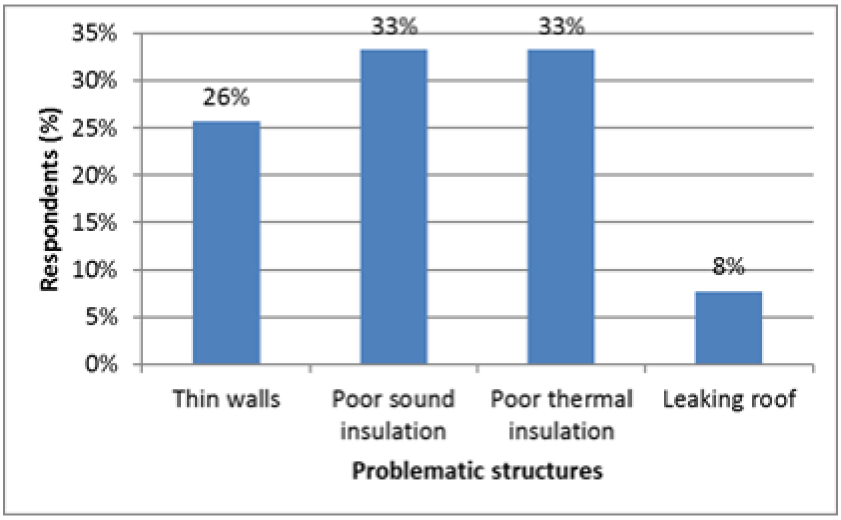

Figure 16: Common infrastructure problems in RDP houses (n= 34 respondents)

Figure 17 shows the cracked and mouldy walls in RDP houses and Figure 18 is an example of a mouldy window seal. This is a clear indication that the moulds spread at a hazardous rate. In fact, living in a mouldy house is a health risk, since mould exposure can result in allergic reactions, alter immunological factors and cause harm to the respiratory tract. These may lead to nasal congestion, coughing, tightened chest and asthma (Curtis *et al.* 2004).

A census report done by StatsSA (2018) revealed that RDP occupants raised concerns about the state of the walls and roofs in their RDP houses. Western Cape, Free State and KwaZulu-Natal had the most complaints when compared to the rest of the other provinces. This is a clear indication that most RDP houses are poorly built on a national scale or the building materials used are not suitable. Another issue raised was weak roofs.

Figure 17: Examples of cracked (A) and mouldy (B, C) walls in RDP houses

Figure 18: Mouldy window seals

The respondents were asked to prioritize and rank the structures that need the most attention and improvement (Figure 19). Most respondents (61%) indicated that walls needed improvement, the second priority was flooring (36%) since the houses come with concrete flooring and the occupants have to install their own tiles or floor boards. The third and last priority was improvements to ceilings (3%).

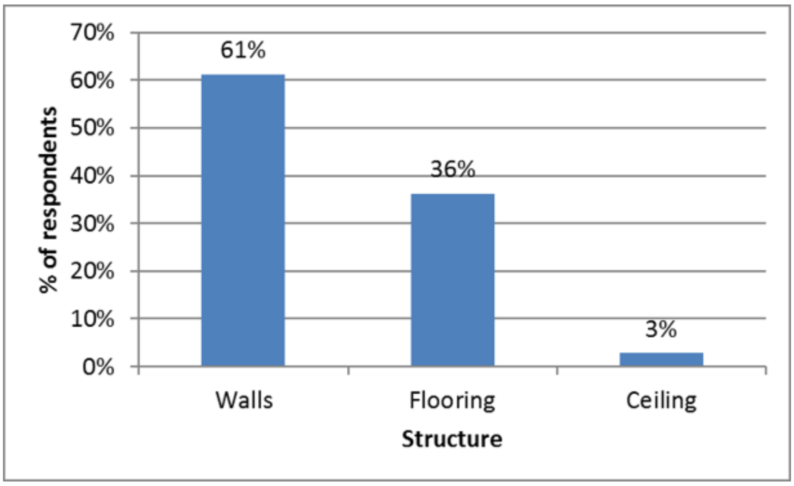

Figure 19: Structures that need the most attention (n=34 respondents)

Suggestions for improvements were asked in an open-ended question and 55% of the respondents said the walls need to be fixed, either by using thicker concrete blocks, or having water proofing material that will block the rain water from contacting the permeable walls, 20% thought installing ventilators would help, 15% wanted the cracked ceiling boards fixed and 10% wanted WPC boards as their flooring, especially for their bedrooms.

When asked what kind of flooring they preferred, 37% respondents opted for their entire houses to have WPC floors, 48 % liked the WPC boards for their bedrooms only. Ceramic tiles on the floors cool the house down during hot days but on cold days the house tends to be very cold therefore the respondents preferred WPC floors. They also loved the aesthetics of the sample boards shown to them during the door to door interviews. 11% of the respondents preferred ceramic tiles and 4% did not have any preference (Figure 20).

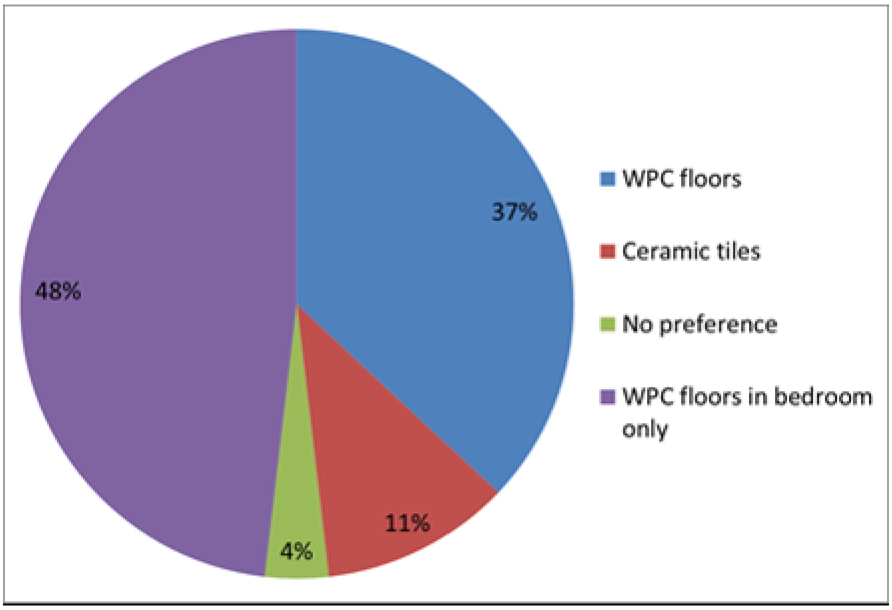

Figure 20: Flooring types preferred by RDP occupants (n= 34 respondents)

The RDP occupants were intrigued by the WPC sample boards, they appreciated the fact that the boards were produced from invasive trees and recycled plastic. Figure 21 shows that most of the RDP occupants (96%) were very open to the idea of WPCs and would not mind if the material would be used to construct structures for their homes. Only 4% were not willing to have these materials used for their house, because they prefer material that is commonly used.

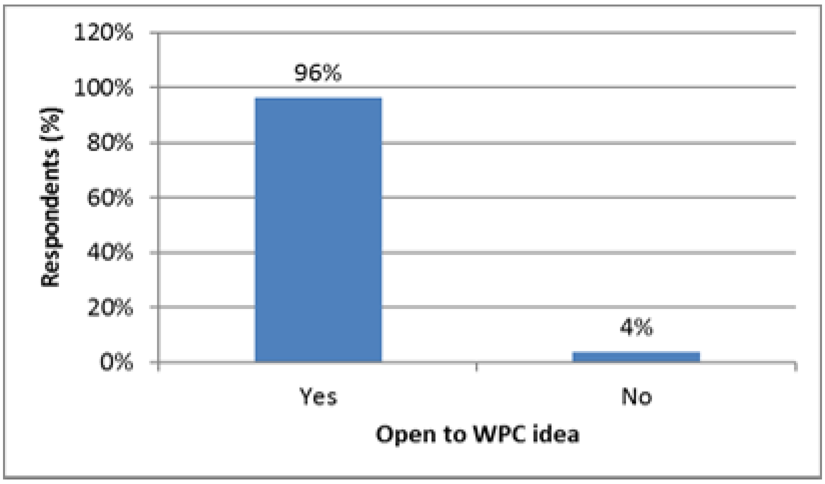

Figure 21: Acceptance of WPC by RDP occupants (n= 34 respondents)

The respondents were asked what additional structures they would be willing to pay for using their own funds (Figure 22). Most of them had no answer since the majority cannot afford to enhance their homes, because they are unemployed or have jobs that pay minimum wage. But assuming that money was not an issue, 55% of the participants opted for WPC floorboards, 39% for wall-cladding and 6% for WPC outside veranda. The new houses have ceiling, therefore occupants saw no need for new ceiling.

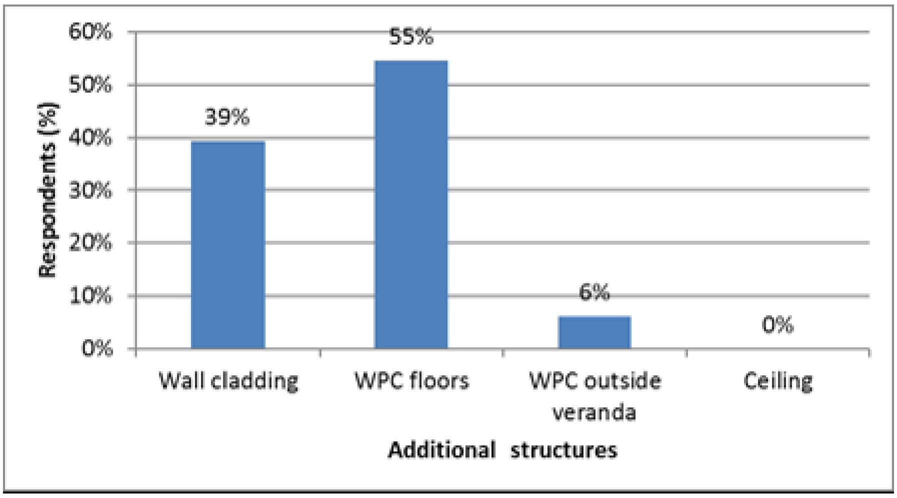

Figure 22: Willingness to use WPC for additional structures on own cost (n=34 respondents)

Based on the assumption that money would not be a problem, the respondents were asked, how much they would pay for additional structures and 53% chose WPC or laminated floors worth R5 000 - R6 000, followed by 25% respondents who chose wall-cladding worth R 400 - R1 500 per square metre with hopes that the additional layer would inhibit the permeable walls from absorbing rainwater, 19% said they could not afford anything and 3% chose ceramic tiles worth R3 500 - R4 000 (Figure 23). All these prices were quotations from building material shops.

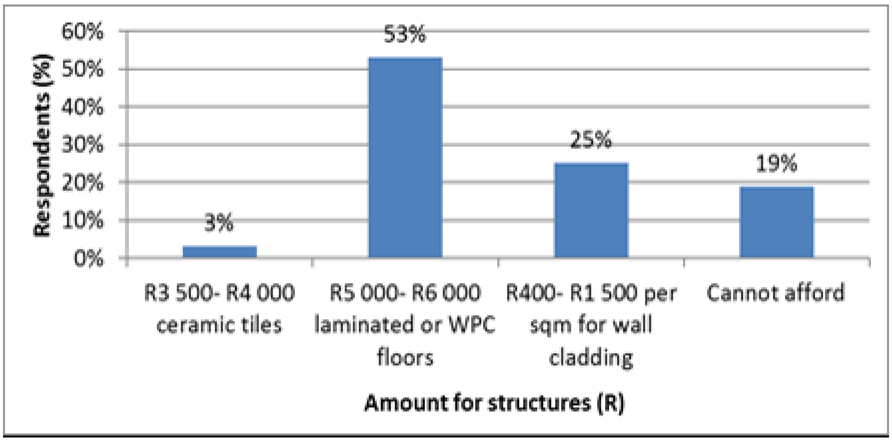

Figure 23: Price limit RDP occupants are willing to spend on additional WPC structures (n=34 respondents)

In summary, the most alarming problems observed were the mouldy walls and problematic ceiling boards. Majority of the RDP occupants were unemployed or had jobs paying minimum wage. For the people who could afford to enhance their homes, they put ceramic tiles in some parts of the house and not the entire house. The concept of WPCs was very intriguing to them since they could not imagine how these heterogeneous material (biomass and recycled plastic) could mix. Although, majority of the respondents had no financial means to incorporate WPCs into their homes, they were willing to have building structures made from the new material, if the contractors used them for construction.

The following chapter discusses the raw material used for WPC production, their suitability to produce material with specific properties and different WPC production methods.

4 Raw material properties and suitability

Societal needs for building materials and infrastructure require transformational change in techniques and materials based on requirements for lighter-weight, environmentally friendly, carbon-sequestering, renewable and sustainable solutions. This includes methods and resources utilized in various industries, for instance consumer products, construction products, produced from wood and other natural fibres. Despite the fact that products made from solid wood remain important from an economic and practical standpoint, it is advantageous that the technology used for WPC production from renewable resources like IAPs and recycled plastic be understood, applied and enhanced (Stokke *et al.* 2014).

WPCs can be regarded as green products since they are made from renewable resources, contain recycled material, require low maintenance and are durable (Rahman 2002). Green buildings made from green products aim to enhance interior environmental quality, such as excellent acoustics, thermal conductivity, good ventilation and moisture control. In addition, these products aim at optimizing operations and maintenance practices in a cost-effective manner (Ashkin 2007).

Because of the rising emissions of different pollutants and possible global warming results, renewable and eco-friendly construction materials are becoming a significant part in construction, because they act as a carbon sink during their service lives as they remove CO_2 from the carbon cycle and therefore contribute to climate change mitigation (Kutnar 2016).

Climate change due to global warming, exorbitant oil prices and environmental threats have resulted in an increased demand for bio-based products. The construction sector has major environmental, societal and economic impact. Buildings made from wood need less development energy, which results in reduced carbon emissions compared to the buildings of other materials such as concrete, brick and steel (Kunič 2016). Therefore, WPCs are a favourable alternative.

WPCs consist of two key components, wood or non-woody plant fibres and thermosets or thermoplastic in different ratios (Schwarzkopf and Burnard 2016) and potentially other additives. This section describes the raw materials used and their properties, the different methods of WPC production, specific WPC properties, any potential building components that can be replaced by WPCs and the advantages and disadvantages of WPCs.

4.1 Components of WPCs

There is a wide variation of biomass, plastic and additives used for different composite products, and it ultimately depends on the end use of the WPCs and the type of environment it will be exposed to. The raw materials used for production depend on the following: availability, affordability, their natural properties, which can be used to improve the characteristics of the final product and standards that need to be met for the end-use (de Kock 2017).

4.1.2 Wood component

Wood is a porous and fibrous structural tissue usually found in stems and roots of trees and other woody plants. These wood trees can be classified into two categories: hardwoods and softwoods. Not only are these different in their physical appearance, but the wood differs morphologically and structurally (Shmulsky and Jones 2011). According to Schwarzkopf and Burnard (2016), hardwoods provide better tensile strength and heat deflection than softwoods.

These characteristics are crucial, especially when deciding what the end-use of the WPC will be. Some of the most prominent features contributed by the woody component to WPC production are: a wood-like aesthetic, stiffening agent, low density, relatively high mechanical properties such as specific modulus and specific strength, low cost, easily incorporated into existing production lines and decreases thermal expansion in the plastic (Hodzic and Shanks 2014; Schwarzkopf and Burnard 2016; Thakur 2015). Some advantages for using wood include its availability (virgin or waste- sawmill trimmings, IAPs), and the fact that it is a renewable resource. Using wood fibres to produce affordable yet sustainable composite materials has become a subject of importance.

4.1.2.1 Tree biomass

The biomass used in this project was *E. camaldulensis*, *Acacia mearnsii* and *A. saligna.* Based on various tests in a related project, *A. saligna* proved to be the best choice and was used as the primary biomass for the WPC production (Figure 24).

A. saligna is an evergreen medium-sized hardwood tree, with a willow-like appearance known to invade the fynbos biome, roadsides and areas near water sources. The leaves droop and the tree has bright yellow flowers clustered in globose. The tree is declared as category 2 invader in South Africa (van Wyk and van Wyk 2013).

Figure 24: Milled *A. saligna*

4.1.3 Recycled polyethylene

When producing WPCs it is imperative to select a polymer of high performance, which is technically and economically suitable. As previously mentioned, polyethylene (PE) has the largest global production. PE has a relatively low-melting temperature (106-130 °C, based on the density/branching of PE) and can be created in a broad-spectrum of viscosity when melted. Once melted, it can mix well with fillers and the low melting point permits the use of cellulose fibres as fillers, without much risk of significant thermal degradation, since melting is below 200°C (Cogswell *et al.* 2016; Schwarzkopf and Burnard 2016).

PE is a soft material, hence WPC products made from it are relatively easy to work with (sawn, cut, screwed and nailed). In addition, PE shows a moisture absorption of close to zero (normally less than 0.02% after a 24hrs underwater immersion). Although PE is not strong, it is flexible and compared to wood, PE has a higher thermal expansion coefficient. PE is made in several polymeric forms, differing in molecular weight and linearity, branches or saturation. This then determines particular properties, such as specific gravity or density and melting flow index used as a way to classify polyethylene. Some forms of PE include: high-density polyethylene, medium-density polyethylene, low-density polyethylene, linear low-density polyethylene, very low-density polyethylene.

For this project, recycled LLDPE was used (Figure 25), which has approximately the same density as LDPE, but the linearity of HDPE. Branches of LLDPE are fairly short and the melt flow index differs from 0.1 to 100 g/10 min (Klyosov 2007).

Figure 25: Recycled conglomerated LLDPE plastic

Table 7 shows the different properties of LLDPE plastic such as the density, shrinkage percentage, water absorption percentage which are essential properties to know before producing WPCs for different end uses.

Table 7: LLDPE properties adapted from (Biron 2013)

Properties	Density (g/cm^3)	Shrinkage (%)	Absorption of water (%)	Tensile strength (MPa)	Elongation at break (%)	Tensile modulus (GPa)	Flexural modulus (GPa)	Coefficient of thermal expansion (10^{-5}(1°/C)
LLDPE	0.915-0.950	2-2.5	0.005-0.010	25-45	300-900	0.266-0.525	1.8-2.1	>9

4.1.3.1 Effects on the further product quality

Plastic recycling receives heightened attention as a means of meeting environmental requirements. The use of recycled plastic reduces waste and decreases virgin material consumption. LLDPE is a thermoplastic, hence several cycles of heating, cooling and shaping can occur repeatedly without severe damage, allowing reprocessing and recycling to occur. Wood fibres are added to the plastic to improve the mechanical and physical properties of the end product. There are numerous possible applications for WPCs made from recycled plastic especially in the construction industry for walling and outdoor furniture. These WPCs can be moulded into a variety of shapes suitable for different applications. They can be used as an alternative for wood, metal and other expensive materials in flooring, fences, railings, facades, decking, and ceilings. Their use in construction is governed by numerous international standards (Hodzic and Shanks 2014).

4.2 WPC production

4.2.1 Compounding

This is the process of mixing wood fibres and thermoplastic in granular or pelletized form. These heterogeneous raw materials further break down when compounded (Figure 26). The temperature has to be high enough throughout the process to have the thermoplastic in a liquid state. Natural fibres are known to degrade at fairly low temperatures and progressively with higher temperatures. Therefore the compounding temperature has to be retained as low as possible and the thermoplastic choice for such composite systems is restricted to those with low melting points normally less than 180 °C. The aim for compounding is to blend polymers, plant fibres, and potentially fillers and additives to achieve an even dispersion and distribution of material, to avoid fibre degradation and to produce pelletized feedstock for further processability. Compounding can be carried out in a continuous screw extruder or a batch mechanical blender (Stokke *et al.* 2014).

Figure 26: Compounded biomass and plastic

The compounded material can undergo a range of different processes to transform it into composites, including extrusion, injection moulding, compression moulding and thermal forming. On a global perspective, the extrusion process is by far the most popular method of WPC production (Hodzic and Shanks 2014), because it is the easiest and most efficient way to produce boards, which can be used for a wide range of applications such as decking, cladding, ceiling material, furniture, wall boards and interior decoration (Kollmann and Côté 2012). This is the process to be used for the WPC production in the project.

4.2.3 Advantages and disadvantages of using WPCs

There is a global reasoning trend supporting the use of WPC material as an alternative for solid wood, metals and other costly material. Some of the advantages of WPCs are that they are eco-friendly, use local undesirable raw material, lightweight, inexpensive, durable, need minimal maintenance and are easy to install. The major disadvantage could be photo degradation caused by ultraviolet (UV) radiation, which could be improved by adding UV stabilizer (Hodzic and Shanks 2014). In the project's context, this is not a hindrance since the proposed application for this project is producing ceiling boards for the interior.

4.3 Sample board production and properties

The mechanical properties of WPCs are highly formulation dependent. The quality of material used (wood fibres, thermoplastic and any additives) play a major role in determining the quality of the final composite product. Mechanical and physical properties, like stiffness, strength, impact resistance and density, determine the suitability of these products in various applications (Niska and Sain 2008). A potential building component that could be replaced in RDP houses by WPCs are ceiling boards currently made from gypsum.

In a related study by Acheampong *et al.* (2019), 4 mm thick sample WPC boards were produced from 60% wood flour from *A. saligna* and 40% recycled LLDPE. In the study, the raw materials were compounded for 15 minutes until the temperature reached 170°C. The blended substance was left to cool to room temperature and pelletized, thereafter the material was hot-pressed in a metal mould with dimensions 250 mm × 170 mm × 4 mm at a temperature of 180°C for 15 minutes to produce sample boards.

The mechanical properties of the presently used gypsum Nutec boards were used as a benchmark that need to be met for ceiling board application, specifically a target thickness of 4 mm, a density of about 1.26 g/cm^3, a MOR of 10.4 MPa, a tensile strength of 2.5 MPa and a maximum water absorption of 37% (see Table 4 in Chapter 2).

The resulting boards, from the related study by Acheampong *et al.* (2019) had a density between 1.06 and 1.15 g/cm3, which affects most mechanical and physical properties of a board. Consumers prefer low density materials with suitable strength (Kollmann and Côté 2012). The boards had MOR values between 35-40 MPa and a tensile strength between 15-19 MPa. The water absorption was 14.3%. All mechanical properties of the WPC board's values exceeded the benchmark values of the gypsum boards. In conclusion, the WPC boards produced from *A. saligna* and recycled LLDPE fulfilled the criteria for ceiling production. If the sample boards would be enlarged they would meet the benchmark requirements of what is already in the market.

Additional tests that should be performed depending on the end-use of the final product include: UV degradation, acoustic and thermal insulation and fire resistance.

4.3.1 Potential replacement

WPC ceiling boards could potentially replace the gypsum ceiling boards currently being used. In a study done by Shebani *et al.* (2009) on the effects of different wood species on mechanical and thermal properties of WPC, the use of *Acacia* resulted in a WPC with superior mechanical properties and thermal stability compared with the other species (eucalypt, pine, oak), due to its higher cellulose and lignin contents and a favourable wood fiber length distribution; however, *Acacia* composites also showed a higher water absorption rate due to the higher cellulose content. However, this is not a critical issue since the proposed building component will be ceiling boards used for the interior of RDP houses. The study also found that WPCs containing wood species with a high lignin and extractive content, such as *Acacia* and oak, had a higher resistance to UV degradation (Shebani *et al.* 2009). Therefore, using *Acacia* for ceiling board production is ideal.

4.4 Market trend in South Africa

The WPC concept is relatively new in South Africa. According to Schwarzkopf and Burnard (2016), WPC products have been developed intensively over four decades and the first few products can be traced to an automotive company (Fiat) in 1972 (Cogswell *et al.* 2016).

Like any new product in the market, the WPC market took a few years to gain traction. Today it is in an established industry finding its niche in the following sectors (Hodzic and Shanks 2014):

- Construction - decking, cladding, pre-finished floorboards.
- Industrial/infrastructure - outdoor furniture, picnic tables, benches, refuse bins, packaging
- Other – dog kennels, pot plants

According to de Kock (2017), the WPC industry was introduced into the local market in the early 2000’s and out of the listed companies in Table 8, only two companies produce their products locally while the rest of the companies import their goods either from China, Germany or USA. Table 9 shows a detailed list of WPC products sold in the South African markets by the different WPCs companies.

Table 8: A list of WPCs companies in South Africa and their product focus (de Kock 2017)

Company name	**Company location**	**Product focus**	**Production location**	**Source of products**
Primwood	Hermanus (WC)	Outdoor furniture	Local	Hermanus
NuDeck	Pretoria (GP)	Decking	Import	China
NPP	Cape Town (WC)	Decking	Import	Germany
EnviroDeck	JHB/CPT (GP/WC)	Decking	Import	China/ USA
Eva-last	CPT (WC)	Decking	Import	China
4Ever Deck	Durban (KZN)	Decking	Import	-
EcoWood (Agrilinga)	Nylstroom (Limpopo)	Decking	Local	Nylstroom

Table 9: List of products sold by WPCs companies in South Africa (de Kock 2017)

Company name	Products sold
Primwood	Planks, furniture sets, staircases, balustrades, dog kennels, lattices, refuse bins, pot plant holders, workbenches, pallets, walkways, bridges, picnic tables, benches, pool loungers, tables, coffee tables, chairs and jungle gyms.
NuDeck	Decking, pergolas, jetty, gates, screens, louvre, cabins, lapa, bridges, wall cladding, doors and fencing.
NPP	Decking, cladding, decking accessories
EnviroDeck	Composite decking, composite cladding, outdoor showers, outdoor composite furniture and composite garage doors.
Eva-last	Decking, cladding, Snap & Go™, railings, furniture, fasteners and flower beds
4Ever Deck	Decking, decking tiles, cladding, fascia, railings
EcoWood (Agrilinga)	Decking, decking accessories, facia

5 Feasibility study

A feasibility study is commonly defined as a well-thought-out way to efficiently organize information that is needed for proper decision-making regarding the profitability and the technical, social and environmental viability of any business proposal (Thompson 2005). Conducting a feasibility study facilitates the investigation of opportunities and strengths of a business proposal.

The four key aspects used to determine the possibility of establishing a new business include: marketing, financial, technical, social and institutional aspects, as well as availability of resources and environmental considerations (Lecup and Nicholson 2000). Prior to evaluating a business' viability, a business opportunity should be identified. Based on the door to door surveys conducted in Kayamandi, 14% of the respondents complained about defective ceiling boards in their houses (cracked ceiling, ceiling that absorbs rain water). Therefore, in this study, the proposed business enterprise was to start a small-scale WPC company producing ceiling boards for low cost housing in Western Cape.

Once an opportunity is identified and the four main aspects are deemed viable the project can be pursed and commercialized and if not viable the project needs to be terminated (Figure 27). An important result from this study would be to evaluate how practical and profitable WPC material used as ceiling boards are for social housing like RDP houses in South Africa. If feasible, the outcomes from this study can be utilized to compile a business plan in order for the proposed product to be commercialized.

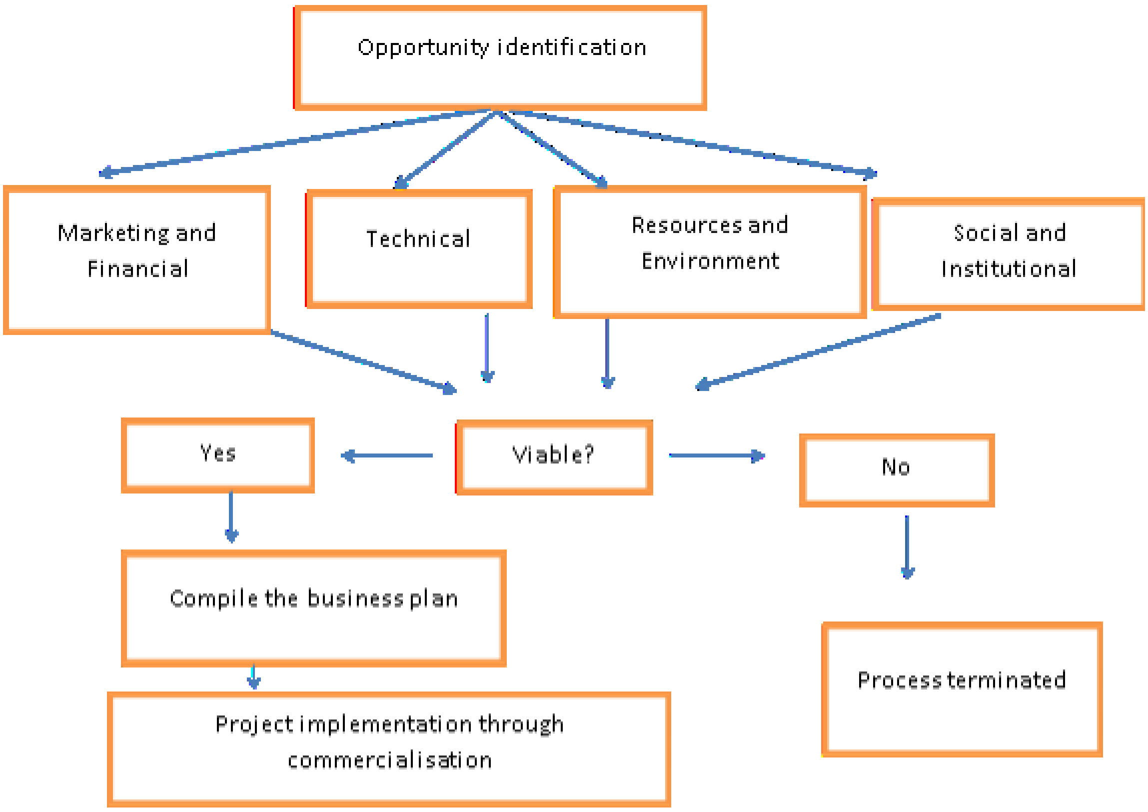

Figure 27: Flowchart evaluating the viability of new business opportunities, adapted from Adam and Doyer (2000)

The aim of this chapter is to determine the financial health status, the break-even price, the break-even units, break-even Rand value, net-present value, project profitability and how sensitive the break-even point is to a change in the selling price and the other input costs.

Two ceiling board types with different dimensions are proposed for the small business. The first board type (1 m x 1 m x 0.004 m) will primarily be used as a research prototype, which can further be up-scaled for commercial purposes. For simplistic calculations and to determine a generic price, these 1 m x 1 m x 0.004 m boards (Type A) allow the calculation of a functional unit (price per m^2) which makes comparison to other products easier. The second board type (Type B) will be based on the dimensions of the gypsum ceiling boards currently in the market, with dimensions of 3 m x 1.2 m x 0.004 m. Both these board types need to satisfy a target density of 1 260 kg/m^3.

The final decision on which dimensions to use for the proposed business will be based on the practicality, usability, affordability and profitability of the product, taking into consideration the cost of production. The product must meet the needs of the market, have an attractive selling price and still generate profit for the business.

A summary of this hypothetical small WPC business is that it will operate for seven hours/day in year one and increase to eight hours/day in the second year, two workshop employees will produce the boards, a loan of R3 500 000 will be used as capital to purchase the machinery and buy the raw material, the boards produced will have a ratio of 60:40 (biomass to plastic). Type A requires total raw material (biomass and plastic) of 110 t and 125.8 t for year 1 and 2 respectively, Type B requires total raw material of 396.2 t and 452.9 t for year 1 and 2 respectively. In addition online stores and local stores will be used to estimate realistic costs of the machinery proposed for the production line. These costs are essential in calculating whether the business is profitable or not.

5.1 Resources and Environmental feasibility

This assessment entails the determination of the raw material supply, procurement costs, the potential of increasing production and the impact it has on the environment once collected. The aim of the project is to utilize eradicated IAPs and recycled plastic and therefore minimize the negative impact they have on the environment.

The ease of obtaining raw material must be evaluated before establishing the infrastructure in a certain location. Determining the raw material input supply is extremely important since transforming these raw materials will generate revenue (Jordaan *et al.* 2004).

5.1.1 Raw material supply

The supply of raw material is imperative since the conversion of inputs is the main function of a processing facility. If the raw materials are not suitable or the quantity is low, processing difficulties will occur during further processing and losses will be incurred. Efficient procurement of raw material is dependent on these characteristics: adequate amount of inputs, suitable quality, affordable costs of inputs and the regular availability of inputs (Jordaan *et al.* 2004b).

5.1.1.1 Adequate quantity of input

The procurement of biomass and recycled plastic input must be evaluated before establishing the manufacturing plant. The quantity of the raw material used determines the quantity of products, which can be produced.

The production of one Type A ceiling board requires 3.024 kg biomass and 2.016 kg plastic and one Type B board uses 10.886 kg biomass and 7.257 kg plastic. The daily production of the boards is dependent on the hot-press machine.

For the purposes of the financial analysis, we assumed that 30 t of woody biomass will be cleared per ha. In reality, one clearing company working under the WfW programme supplied biomass for the production of the WPC sample boards estimated that it cleared 598 t biomass in 2017/2018. This is sufficient for the production of the WPC ceiling board production.

The biomass proposed for this project will be cleared along the Berg River in Paarl, which is 30-40 km away from the proposed processing location in Stellenbosch. The amount of biomass depends on how dense the vegetation in the area to be cleared is. Based on the 598 t cleared biomass in 2017/2018, it could be assumed that there is adequate biomass available for the enterprise to produce either one of the boards since 66 t and 237.7 t of biomass is required for Type A and B respectively for year 1. The second year requires 75.5 t and 271.7 t of biomass for Type A and B respectively.

The buy-back (recycling) factory supplying plastic estimated that it produces about 100-700 t of recycled plastic monthly, indicating that there would be sufficient plastic supply for the small business.

5.1.1.2 Procurement costs of raw material

The costs incurred during the procurement of the raw material needs to be evaluated. Harvesting and transporting costs are very site specific and depend on various factors, such as the type of biomass being eradicated, density of biomass on the area, slope, fuel costs and labour costs. Clearing IAPs is expensive, but necessary (Krug *et al.* 2010).

The 2009 historical IAPs harvesting costs for a hectare plot obtained from the Flower Valley Project conducted by Shuttleworth and Ackerman (2009) were adjusted for inflation to allow for the passage of time by using the Stats SA Producer Price Index (PPI) for Agriculture, Forestry and Fishing on an Excel spreadsheet. The PPI is defined as “a measure of the change in the prices of goods either as they leave their place of production or as they enter the production process (StatsSA 2008). Based on the data used, the inflated clearing cost to harvest 30 t per hectare was R10 785.80/ha (appendix 3A). This includes the labour costs and machinery used for harvesting.

The transportation calculations were adapted from a study done by Mugido *et al.* (2014), which determined the cost of clearing and transporting IAPs, such as gum, wattle and pine species for energy. The transport costs in the study were based on actual invoiced costs for transporting approximately 30 t woody biomass for distance radii between 30 and 50 km. The historic invoiced costs were inflated using Stats SA PPI for Agriculture, Forestry and Fishing. The estimated costs of transporting the solid wood for two 40 km trips (15 t per trip) is R4 886.67/ha when using a 6 x 4 rigid truck having a payload of 15 t. The transport costs should include fuel costs, loading and unloading costs, potential loads daily, distance, downtime duration and truck payload (Kitenge 2011; Shuttleworth and Ackerman 2009). The total biomass procurement costs for clearing 30 t woody biomass per hectare is R15 672.48/ha. Therefore, the total cost for obtaining woody biomass sourced from one hectare would be **R522.42/t** (**R0.52/kg)**. Detailed transport calculations are attached in appendix 3B.

The purchasing price for recycled plastic is a fixed **R4 500.00/t** (**R4.50/kg**) for the C grade LLDPE plastic from a recycling factory. The high price per ton is expected considering that the buy backs purchase waste plastic from waste collectors and pay approximately R1 200 - R9 000/t. It is evident that the purchasing price for the recycled plastic is more expensive than sourcing biomass.

The costs of obtaining the raw material must be recovered in the revenue during the sales. Obtaining biomass will cost R34 180.54 for Type A board production and R124 209.07 for Type B board production per annum, which would take into account clearing, loading, unloading and transport costs for full trees. It would cost the business approximately R198 720 to purchase recycled plastic for Type A board production and an estimated R713 276.93 for Type B production in the year of establishment. Additional transport costs to deliver the plastic would have an estimated cost of R400 per trip (25 t per trip) from Bellville to Stellenbosch.

5.1.2 Potential to increase production

The business has the potential to expand, especially if the profits are reinvested into the business to purchase more machinery and inventory and because there is ample recycled plastic and invasive trees available. As mentioned, the recycling plant produces 100-700 t of recycled plastic monthly and invasive tree supply may vary from area to area, but there is enough biomass for the expansion of the business. In the year of inception Type A board production would need 5 520 kg of biomass and 3 680 kg plastic monthly. Type B board production would need 19 813 kg of biomass and 13 209 kg per month. In the second year the production time would increase to eight hours in order to increase the quantity of boards to be produced. Therefore, the biomass required for Type A boards would increase to 6 300 kg and 4 200 kg for plastic per month. Type B boards would require 22 644 kg of biomass and 15 095 kg for plastic per month.

Other types of biomass could potentially substitute the invasive woody trees proposed to be used, however further tests would have to be done regarding the properties of the resulting WPCs depending on the end use.

5.1.3 Environmental feasibility

The intention of using IAPs and recycled LLDPE is to try minimize the negative impact they have on the environment. Hence, using the cleared biomass to produce valuable and practical products is not only environmentally beneficial, but economical since the government spends an estimated R1.5 billion annually trying to eradicate IAPs (van Wilgen and Wilson 2018). Introducing the WPC ceiling boards to the VAI would guarantee economic benefits. Plastic pollution caused by poor waste management or littering can harm and kill land and water animals (Parker 2019). Therefore using waste plastic can combat the negative effects they have on the environment.

5.2 Social and institutional feasibility

The assessment entails investigating the indirect benefits of the project for the community and potential job creation. As mentioned in a previous chapter, the official unemployment rate for Western Cape is 20.4% (StatsSA 2019) and the majority come from the previously disadvantaged groups. The communities around Stellenbosch could benefit immensely from this proposed business through potential job creation. Several funding organizations grant support to previously disadvantaged groups and this criterion could help acquire the funds to start the business.

5.2.1 Benefits of the proposed small business enterprise

The direct benefits of this entire project include the potential to create employment opportunities in various sectors of the business stream, such as clearing and transporting biomass, subsistence waste pickers and the people who work at buy-backs. These jobs are already available, however the project will aim to employ two people for the WPC production business.

Another direct benefit is job-training for the two people who will manufacture the boards in the year of inception. Once the business expands and more funds are available, more people could potentially be trained and employed. In addition, a cleaner who will ensure the manufacturing area and office space are clean, an admin officer, who will ensure that the telephone and business emails are attended to and the manager/owner who will overlook the business and make business decisions will be employed by this small business. Therefore, a total of five people would be employed by this proposed business.

An indirect benefit could be that more people would be made aware of becoming informal waste pickers and earn money or participate in the Stellenbosch Swop Shop which is a recycling initiative by municipality. Such things will encourage people to recycle their waste and decrease the number of impoverished households in the communities. In addition the locals may be made aware that waste products could be recycled and transformed into new reusable and practical goods like WPCs products.

5.3 Technical feasibility

This entails investigating if the proposed project is possible with current technology. The assessment evaluates a proposed processing location, technology needed and human resources/skills.

5.3.1 Workshop location

Establishing the manufacturing facility in a suitable location is essential and different factors need to be considered. These include:

- Easy access to raw material
- Easy access to the target market
- Easy access for labourers to the processing plant and
- Good infrastructure (water, electricity, road network).

After considering the numerous factors from above, the location of the production plant was set to be in Stellenbosch. The decision was based on the following:

- There is available infrastructure such as old, vacant buildings, which can be utilized to establish the WPC production plant
- All utilities, such as electricity and water are available
- Kayamandi, Nyanga, Gugulethu and Khayelistsha Townships are areas where low cost houses are being constructed and are in close proximity (24-35 km), meaning the factory would be easily accessible to contractors wanting to purchase WPC ceiling boards.
- The biomass will be sourced from Paarl and the recycled plastic will be sourced from Bellville. Both areas are 30-40 km away from Stellenbosch and
- Access to excellent road network

There are communities around Stellenbosch that have a high number of unemployed people who could be trained to produce the WPC ceiling boards.

5.3.2 Status of the workshop

At the time of writing, a section of a shutdown sawmill is proposed to be the WPC workshop. The status of the current infrastructure at Stellenbosch is satisfactory to establish this small business enterprise that is proposed by the feasibility study. The facility has good manufacturing space, accessible road network and good water and electricity connection.

5.3.3 Machinery

5.3.3.1 Selection of machinery used

The type of machines, purchase prices, running costs and throughput will be discussed in this subsection. The various factors used to select the processing technology are discussed.

The technology used needs to meet the qualitative requirements of the ceiling boards to be produced. It is imperative to choose the suitable technology that will meet the quality standards selected by the South African National Standards (SANS) or using existing products as benchmarks.

Affordability is very important, since this is a small business enterprise. Another important factor is the quantity of raw material obtained. The quantity to be introduced daily into the production process should match what the machines can process daily. The factory machines should never run under capacity, since this may increase cost of production.

The flow diagram (Figure 28) shows the production line and types of machines used to produce the WPC boards, whereby the biomass is chipped and milled to reduce the particle size, the 60:40 ratio of biomass and recycled plastic is compounded in a blender for 15 minutes to melt the plastic and mix it with the wood flour and finally the blended material is hot-pressed in either a metal mould with dimensions 1 m x 1 m x 0.004 m or 3 m x 1.2 m x 0.004 m depending on the product type being produced for 15 minutes in a hot pressing machine to produce the desirable boards.

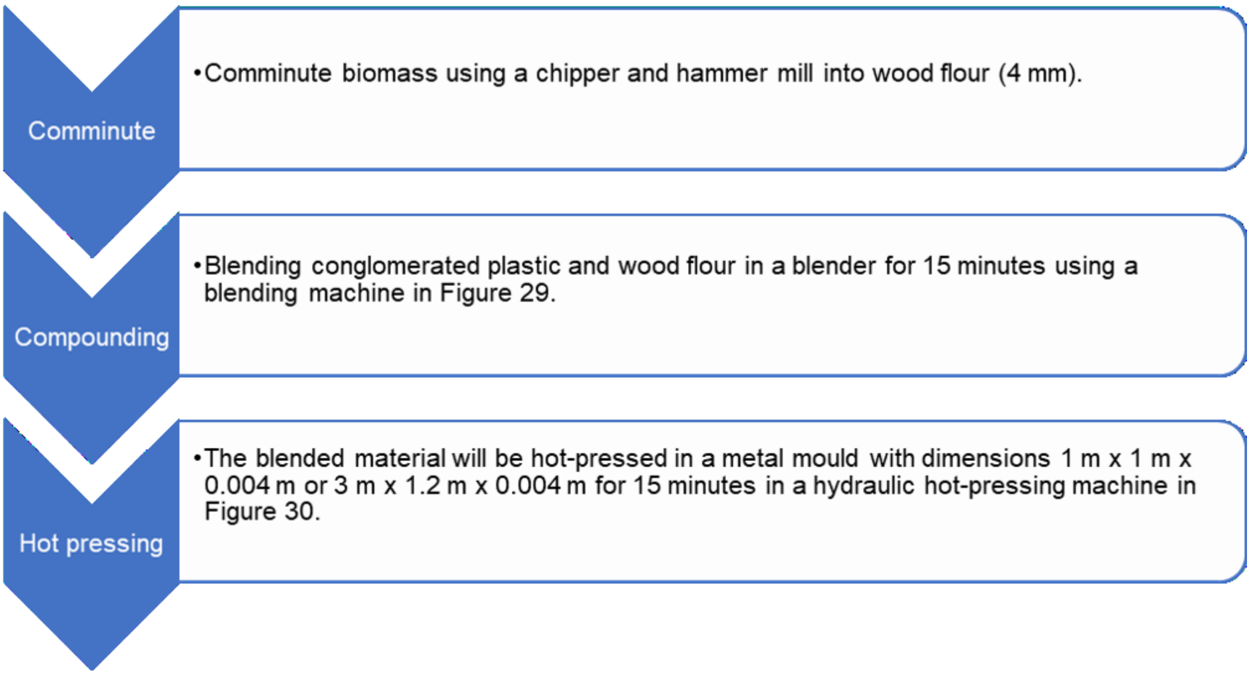

Figure 28: Production line and technology used to produce WPC ceiling boards

The machinery suppliers used included online stores and some local shops to get a realistic idea of their purchase prices and throughput. The machines used for the ceiling board production are: a chipper, hammer mill, blender and a hot press. Figure 29 shows a multi-layered hot-press, which has suitable specifications to produce the desirable ceiling board dimensions for the proposed small business. It is an integral part of the entire production line since it determines the quality and quantity of boards to be produced with the help of the metal moulds which determine the dimensions of the boards. Therefore, both board types and their different dimensions can be manufactured, since that is dependent on the metal moulds used (1 m x 1 m x 0.004 m mould for Type A boards and 3 m x 1.2 m x 0.004 m for Type B boards). The blender and hot press will incur shipping costs because they will be purchased from overseas.

The assumed shipping costs of R10 000 and R15 000 for the blender and hot press were added to the purchasing price. The chipper and hammer mill would be purchased from local stores and would not incur shipping costs.

Figure 29: Example for a blender to be purchased from Abelplas (2019) and used for compounding

Figure 30: Example of a multi-layered hydraulic WPC hot-press machine to be purchased from Qdguosen (2019)

The machine prices range from R50 000 for the chipper, R114 790.78 for the hammer mill, R227 000 for the blender and R2 600 240.04 for the hydraulic hot-press, which is the most expensive part. The total machinery costs amount to R2 992 029.82 and could be deemed as the initial investment for the business, which will be essential when calculating the net present value. The hot-press produces thirteen boards per hour for seven hours daily, resulting to ninety one boards daily. The other machines will have different running times depending on their throughput and how much raw material is needed for pressing.

The required raw material has to be aligned with the capacity that each machine can process in order to meet the required masses (276 kg biomass and 184 kg plastic for Type A boards and 991 kg biomass and 660 kg recycled plastic for Type B boards) to produce the ninety-one boards daily. The total electricity usage varies between the two board production lines because the hammer mill has to run for an extra hour since the mass throughput per hour could not meet the quantity required for the daily production for Type B boards. To determine how much money is required to run the machines, the cost of electricity usage is given below.

$$Cost\ of\ electricity\ usage = kWh * Cost\ per\ kWh * number\ of\ hours \tag{1}$$

The cost for running the machines to produce Type A boards per day is R436.45 and R468.27 for Type B boards. Tables 10 and 11 give a summary of the machines used for each production line, the individual electricity costs of each machine and their throughputs for Type A and Type B boards, respectively and only differ with the additional hour on the daily operating time on the hammer mill when producing Type B boards. Type A boards would require 276 kg biomass yet the hammer mill's throughput is 500 kg/hr therefore, it would run for one hour as opposed to two hours when producing Type B boards because 991 kg biomass is required. It is evident that the factory machines in this production line ran under capacity when producing the Type A boards. It is extremely important to maximize the use of the production machines in order to generate good returns.

Table 10: Machine costs, running costs and throughput for Type A boards (1 m x 1 m x 0.004 m)

	Chipper	Hammer mill	Blender	Hot press	Total costs
Machine costs (R)	50 000.00	114 789.78	227 000.00	2 600 240.04	2 992 029.82
Electricity required (kW)	7.5	37	42	22	
Cost of kWh	R 0.86				
Daily operating hours	3	1	7	7	
Cost of electricity per day(R)	19.35	31.82	252.84	132.44	436.45
Throughput	2 tons/day	500kg/hr	240-800kg/hr	13 boards/hr	

Table 11: Machine costs, running costs and throughput for Type B boards (3 m x 1.2 m x 0.004 m)

	Chipper	Hammer mill	Blender	Hot press	Total costs
Machine costs (R)	50 000	114 789.78	227 000.00	2 600 240.04	2 992 029.82
Electricity required (kW)	7.5	37	42	22	
Cost of kWh	R 0.86				
Daily operating hours (hrs)	3	2	7	7	
Cost of electricity per day (R)	19.35	63.64	252.84	132.44	468.27
Throughput	2 tons/day	500kg/hr	240-800kg/hr	13 boards/ hr	

All machinery wears off over a period of time and the business needs to account for that. The machines used in the production line and administration equipment used in the office will depreciate uniformly (Lessambo 2018) on a straight-line basis. The machines have different useful life (years), which can be defined as the period an asset is expected to be productive. Acknowledging this is beneficial when calculating depreciation costs of the various machines used and the total periods to be paid. The computer and printer each have five useful years, chipper and hammer mill each have ten useful years and the blender and hot press each have fifteen useful years. The total depreciation cost for all the machine is R15 457.59 monthly and R185 491.12 annually (Table 12). These amounts are subjected to change after five years once the administration equipment have reached their useful lives.

Table 12: Straight-line depreciation method used for the small business equipment

Workshop machines					Admin equipment		
	Chipper	Hammer mill	Blender	Hot press	Computer	Printer	Total
Machine cost (R)	50 000.00	114 789.78	227 000.00	2 600 240.04	3 199.00	2 499.00	
Depreciation %	10%	10%	10%	10%	10%	10%	
Salvage value (R)	5 000.00	11 478.98	22 700.00	260 024.00	319.90	249.90	
Useful life (yrs)	10	10	15	15	5	5	
Depreciation/yr (R)	4 500.00	10 331.08	13 620.00	156 014.40	575.82	449.82	185 491.12
Depreciation/month(R)	375.00	860.92	1 135.00	13 001.20	47.99	37.49	15 457.59

5.3.4 Labour and skills

The project is aimed at becoming a small-scale business with low operational and maintenance requirements in terms of human resources and skills. Therefore, labourers will be trained on the job on how to use the processing machines. At the time of inception of the business only two workers will be trained and employed. With the expansion of the business gradually more people will be trained and employed. Two labourers are sufficient to manually handle the raw material required on an hourly basis for production of thirteen boards because only 65.52 kg and 235.87 kg for Type A and Type B is needed. This translates to 458.6 kg and 524.16 kg daily for year 1 and 2 respectively for Type A. Type B would require 1 651 kg and 1 886.97 kg per day in year 1 and 2 respectively.

5.3.5 Distribution

The proposed distribution channel would be to deliver directly to the building sites for the building contractors to use the ceiling boards during construction, until the product has gained traction and the target market has expanded. In future, big hardware stores such as Cashbuild and Build It may stock from the business to resell to consumers. Selling directly to the building contractors as opposed to selling through hardware stores will keep the selling price low, while a niche market is developed, because hardware stores would add on the selling price from the WPC factory to gain profits (mark-up). The ceiling boards could be sold to building contractors constructing RDP houses in Kayamandi Township and in other townships close by, such as Khayelitsha, Gugulethu and Nyanga, where other types of social houses besides RDP houses are currently built by the government.

These other state social housings provide medium density, affordable, rental housing to low-medium income people. These forms of social housing are a way for the government to try bridge the gap for people who earn more than R3 500 and less than R15 000 monthly, which means they earn too much to qualify for RDP houses, but too little to qualify for a home loan (DHS 2019).

Direct delivery of the ceiling boards can be done in two different ways. The first is to transport the boards using the building contractors transport and the second way is for them to hire a second party to transport the boards to the site. This means the ceiling boards will be sold directly at the manufacturing plant. Only marketing costs would be incurred (accounted for in the budgeted income statement) and no distribution costs will be incurred since the boards will be directly sold from the manufacturing plant.

5.4 Marketing and financial feasibility

This is the assessment of possible target markets, competition and constraints to business entry. The marketing and financial aspect is essential in identifying a niche in the market and gathering information about the industry. The procurement costs for the raw material and production costs are used to determine the net profit after tax, perform the break-even analysis, net present value and sensitivity analysis in the small business.

5.4.1 Market analysis

This involves determining the competition in the market, the market volume and value and forecasts and trends for the WPC industry.

5.4.1.1 Competition and market value

The biggest competition would be the gypsum board market, which is well established in South Africa, especially in the construction and building sectors. The South African “home & garden products” has an additional category categorized as “other material”, which includes boards, doors, timber and bricks. This home and garden product market grew by 5.4% in 2017 reaching a value of $7 635.3 million (R113 billion). In 2022, the South African market is predicted to reach an approximate value of $9 989.2 million (R148 billion), a growth of 30.8% since 2017 (Marketline 2018).

The home and garden products market is dependent on the housing development and market because home owners, especially new home owners provide a firm customer base. The gypsum board industry is thriving in Africa due to its low production cost and domestic demand.

However, in Europe and North America there has been a shift in consumer preference towards bio-based materials (GVC 2017), which is something African countries should be aiming to do.

The costs for ceiling boards in the market have different prices and dimensions. All the boards listed below are gypsum boards, from different brands. The ceiling boards currently used for RDP houses cost R109.95 (excluding VAT) in 2017 and have dimensions 3 m x 1.2 m x 0.0064 m (PHP Building Supplies 2017). Nutec boards sold at Cashbuild (2019) for R159.95 have dimensions 3 m x 1.2 m x 0.004 m and will be used to the compare the proposed Type B boards. Gypsum ceiling boards sold at STEP Building Supplies (2019) for R143.52 have dimensions 2.7 m x 1.2 m x 0.009 m and fibre cement boards with dimensions 2.4 x 1.2 x 0.004 m sold at Pelican Systems (2019) cost R144.00. These are a range of prices the proposed WPC ceiling boards need to compete with. The average cost for one ceiling board with dimensions ranging between 2.4 m-3 m x 1.2 m and different thickness is R140.00 based on the market prices given above.

5.4.1.2 Forecasts and trends

The global gypsum board market size was estimated at $37.25 billion (R552.52 billion) in 2018 and is projected to reach a compounded annual growth rate (CAGR) of 11.4% from 2019-2025. Increasing demand from construction industry is expected to drive the market. Emerging economies, like South Africa, have shown great demand for construction materials, due to growing population and rapid industrialization, which caused a surge in the demand for better infrastructure facilities in residential as well as commercial and institutional sectors (GVC 2019).

All proposed boards need to be approved by the South African Bureau of Standards (SABS) and compare favourably to the boards already in the market.

The dominant use for WPC is decking and wall-cladding. This opens a window of opportunity for interior structures to be produced. There is limited data about the WPC market size and value in South Africa. According to Inkwood Research (2019), on a global scale the WPC market is projected to be around $10.678 million (R158 million) by 2027, at a compounded annual growth rate (CAGR) of 11.5% between the forecast periods of 2019-2027.

5.4.1.3 Market opportunities

Based on the market analysis it is clear that there is a business opportunity for the production of WPC ceiling boards in South Africa. WPC ceiling boards are not a common thing, therefore, a business opportunity exists for the local production of WPC ceiling boards to supply the building contractors constructing RDP and subsidy social housing.

5.4.2 Consumer analysis

Initially the target market of the ceiling boards were the RDP occupants, however financial constraints proved be a hindrance for them when it comes to purchasing the WPC ceiling boards. Therefore, RDP building contractors would have to be the main target market.

5.4.2.1 Influences of buying decision

RDP building contractors want to purchase building material that is affordable, easy to install, SABS approved and can be bought in bulk. The biggest buying decision is the selling price of the product since the contractors are also running a business and need to generate profit too. It could be assumed that most contractors have formed strategic alliances with building material suppliers to buy in bulk over long periods of time, in exchange receiving discounts. Therefore, the small business would need to also form partnerships with various contractors and establish a market.

5.4.2.2 Acceptance of the WPCs boards

All the respondents were shown the WPC sample boards with different colours (Figure 31) and they also felt the board strength and stiffness. Most (96%) of the reactions were positive. However, affordability was the main reason they would not purchase from their own personal capacity. Therefore, the boards would have to be implemented through the RDP building contractors once the boards get SABS approved.

In collaboration with government bodies, such as the DEA and DHS the WPC project could be tried as a pilot project to illustrate the benefits of the innovative product.

The selling point for these WPC ceiling boards would be that they are bio-based, sustainable and have better properties than the current ceiling boards used in the RDP houses. In a related study done by Acheampong *et al.* (2019) as mentioned in Page 42 Chapter 4, the WPCs were tested for the various mechanical properties and some results included that they have a maximum water absorption percentage of 14.3%, which is better than the 37% for the Nutec boards. The boards had MOR values between 35-40 MPa and tensile strength between 15-19MPa, which exceeded the benchmark MOR of 10.4 MPa and 2.5 MPa for the Nutec boards currently in the market. The WPC boards are stiff, hence less chances of them cracking and they do not deplete natural resources but rather utilize undesirable waste material from the environment. In addition, the boards are appealing to the eye.

Figure 31: WPC sample boards

5.4.2.3 Summary from the consumer profile

In recent years, there has been a move towards using more environmentally friendly building material and incorporating green products for construction. Hence, using the WPC ceiling boards would assist RDP contractors to achieve that goal. The WPC ceiling board prices need to be as competitive as the prices in the market and strategic alliances between the small business and contractors would need to be developed to ensure that a niche market is established. Contractors utilizing locally produced green products for construction may be awarded for being a sustainable company.

5.4.3 Financial analysis

5.4.3.1 Constraints to business entry

The administrative set up of any business is capital intensive therefore it is assumed that the project will apply for external funding from different organizations. Some constraints for starting a new business in South Africa could be funding, and the acquisition of the state of the art technology used in the production line. However, there are different governmental and non-governmental organizations, which have initiatives to aid start-up companies with funding and other resources. A list of organizations that could help this type of establishment include the Department of Trade and Industry (DTI), which fund businesses from different sectors, the National Empowerment Fund (NEF), which aid businesses from the previously disadvantaged communities and the National Youth Development Agency (NYDA), which helps the youth from the ages 18-35 years old and many other organizations. It is imperative to utilize all the resources available to start a business, especially since it will create employment and grow the country's economy (Funding Connection 2019).

A loan of R3 500 000 would be required to set up the small business in the Western Cape at a prime lending rate of 10.25%. The aim is to repay the loan over a period of ten years. The loan payment formula given below was used to calculate the annual payments and the interest, which is to be paid for the ten-year period of the business' operations.

$$P = \frac{r\,(PV)}{1-(1+r)^{-n}} \qquad (2)$$

Where P= Payment, PV= Present value, r= rate per period, n= number of periods

The amortization table (Table 13) shows the detailed principal amount, interest and amounts to be paid per annum until the loan has been paid off over ten years. An annual repayment of R575 740.56 (R47 978.38 monthly) needs to be paid.

Table 13: Amortization table showing the loan repayments amounts to be for a 10-year period.

Amortization table				
Interest rate	10.25%			
	Principal amount	Interest	Annual repayment	Balance
Year 0				R 3 500 000.00
Year 1	R 216 990.56	R 358 750.00	R 575 740.56	R 3 283 009.44
Year 2	R 239 232.10	R 336 508.47	R 575 740.56	R 3 043 777.34
Year 3	R 263 753.39	R 311 987.18	R 575 740.56	R 2 780 023.96
Year 4	R 290 788.11	R 284 952.46	R 575 740.56	R 2 489 235.85
Year 5	R 320 593.89	R 255 146.67	R 575 740.56	R 2 168 641.96
Year 6	R 353 454.76	R 222 285.80	R 575 740.56	R 1 815 187.20
Year 7	R 389 683.88	R 186 056.69	R 575 740.56	R 1 425 503.32
Year 8	R 429 626.47	R 146 114.09	R 575 740.56	R 995 876.85
Year 9	R 473 663.19	R 102 077.38	R 575 740.56	R 522 213.66
Year 10	R 522 213.66	R 53 526.90	R 575 740.56	R 0.00

5.4.3.2 Raw product composition

The aim is to utilize a multi-layered hydraulic hot press machine to produce thirteen boards hourly and ninety-one boards daily. This projection estimates that 21 840 WPC ceiling boards can be produced and sold in the year of establishment. Hence, 66 044.16 kg of biomass and 44 029.44 kg of recycled plastic for Type A is required for production. Type B boards require 237 758.98 kg of biomass and 158 505.98 kg of recycled plastic for year 1.

5.4.3.3 Key assumptions

Basic assumptions had to be made for the feasibility study. Variable production costs for the production of WPC ceiling boards was based on the market research done. Variable costs are dependent on the quantity of boards produced and raw material ratios used. The variable costs listed below in Table 14 will be used for the break-even analysis. Each Type A board requires R1.57 for the biomass, R9.54 for the plastic and R4.96 for electricity. Type B boards require

R5.69 for biomass, R33.98 for recycled plastic and R5.31 for electricity per unit. Both the boards' costs require the same amount for direct labour and water.

Table 14: Variable costs per unit produced daily for Type A and Type B boards

Variable input costs per unit produced	Type A boards (1 m x 1 m x 0.004 m)	Type B boards (3 m x 1.2 m x 0.004 m)	Location
Biomass	R 1.57	R 5.69	Paarl
Recycled plastic	R 9.54	R 33.98	Bellville
Direct labour	R 3.16	R 3.16	Local
Electricity	R 4.96	R 5.31	Local
Water	R 0.33	R 0.33	Local
Total variable cost per unit	**R 19.56**	**R 48.47**	

The fixed costs per unit are essential in determining the break-even price per unit. It was calculated as the quotient of the total direct annual fixed costs for producing the boards and total annual units produced, which resulted in R61.55 for both Type A and B boards, since they are subjected to the same production and fixed costs remain constant regardless of change in the business model. Fixed costs can be defined as costs that stay constant regardless of the quantity of units produced. This could be loan repayment, salaries, depreciation of machines, insurance, telephone bill and maintenance which remain fixed regardless of the business output (Table 15).

Table 15: Fixed costs incurred in the business monthly

Fixed costs	Unit	Cost (R)
Loan repayment	R/month	47 978.38
Employee salaries (admin officer, manager, cleaner)	R/month	20 000.00
Depreciation (simple line method)	R/month	15 457.59
Insurance	R/month	15 000.00
Telephone and fax	R/month	300.00
Maintenance costs	R/month	1 000.00
Building rental (workshop and office)	R/month	12 000.00

Other key assumptions are listed in Table 16 and will be used when calculating the total sales revenue monthly and annually, which will be beneficial in order to determine key values such as the net present value of the project. The 28% corporate tax will be used to calculate the net profits after tax in the budgeted statement of profit or loss and other comprehensive income. SARS requires businesses which make total sales of taxable supplies exceeding R1 million to register as value added tax (VAT) vendors. It is compulsory for the proposed business to adhere to this policy and charge a 15% VAT on all of its products as it is estimated to have sales exceeding the R1 million benchmark. The VAT inclusive selling prices are not shown in the financial reports as these are not incoming funds for the business.

Table 16: Key assumptions for the financial analysis for Type A and B boards for the first year of production

Other key assumptions	Value
Corporate tax (SARS 2019)	28%
Value added tax (VAT) (SARS 2019b)	15%
Monthly board production	1 820
Monthly biomass required (kg)	5 520 for Type A boards 19 813 for Type B boards
Monthly plastic required (kg)	3 680 for Type A boards 13 209 for Type B boards
Production schedule	7 hours per day 20 days monthly 12 months per year
Net profit after tax calculation	Difference between net profit before tax and taxation
Inflation ((StatsSA 2019b)	4.5%

5.4.3.4 Determination of the selling price

When you run a business, setting a reasonable price for the products you sell is a make or break task. The risk of setting a low price is that the business will not provide sufficient gross profit to cover operating expenses and ensure that the business has a positive bottom line (net profit). Also, a high selling price might have a negative effect of driving away customers.

When calculating the selling price of both Type A and Type B boards, the points mentioned above were taken into account. To calculate the selling price (SP), one needs to divide the total costs of goods sold, which are the direct costs of producing products by the total number of units sold and adding a desired mark-up percentage on the costs of goods sold per unit. This mark-up should yield a selling price which will result in profits for the enterprise but also be competitive when compared to other products in the market.

Ceiling tiles which can be in comparison with Type A boards have dimensions 500 mm x 500 mm sell at a price of R94.95 inclusive of VAT. The cost of producing one Type A board is R42.93 and a favourable mark-up percentage is 110% as this results to a good return and allows the business to trade at a competitive price of R90.16 exclusive of VAT. The selling price which includes VAT would be R103.68 per unit. This VAT inclusive selling price is competitive as the Type A boards have double the ceiling tiles dimensions and the price is nearly the same.

Based on the RDP building material quotation, the ceiling board price was R109.95 excluding VAT in 2017. By using an inflation rate of 4.5% to estimate the selling in 2020, the resulting selling price is R125.47 excluding VAT. The VAT inclusive selling price is R144.29 for the currently used gypsum ceiling boards. The WPC Type B boards with similar dimensions will have a cost per unit of R71.04 and the mark-up percentage on cost of 70%. This will result in a VAT exclusive selling price of R120.76. The VAT inclusive selling price is R138.88 which is still competitive when compared to the price estimated from the RDP building material quotation.

5.4.3.5 Break-even analysis

Categorizing costs into fixed and variable costs can be used to determine the break-even point. This is when an enterprise is neither in loss nor profit (Potkany and Krajcirova 2015). Knowledge of the break-even point is essential because it shows how many units must be sold in order to meet the cost of production. When the quantity of units sold exceed the break-even point, the business is said to be profitable.

The break-even analysis was conducted by:

- Determining the variable costs per unit (biomass, recycled plastic, direct labour costs, electricity and water cost) and fixed cost per unit (including extra costs of the loan repayment).
- Determining the break-even price which refers to setting a price point whereby the business does not earn any profits, but covers the cost of production. This is calculated by dividing the total fixed costs by the annual estimated units to be produced and that resultant value is added with to the variable cost per unit.
- Determining the break-even quantity whilst keeping the selling price fixed (R90.16 for Type A boards and R120.76 for Type B boards).
- Determining the break-even value amount whilst keeping the initial level of sales constant (21 840 units per year). The break-even value shows how much sales in Rand value will need to be made in order to break-even.

The break-even analysis for the boards yielded the following results:

- The variable cost per unit was R19.56 for the Type A boards and R48.47 per unit for Type B boards. The fixed costs per unit was R61.55 for both board types.
- The break-even price is the sum of the variable and fixed costs per unit, therefore set to be R81.11 and R110.02 for Type A and Type B boards respectively.
- As discussed, the selling prices for Type A and Type B were R90.16 and R120.76 (VAT excluded) respectively since that is the price that will only be reflected in the business' financial books.
- The contribution margin was R70.60 and R72.29 for Type A and B boards respectively. The contribution margin is the difference between sales price and variable cost. This is an important value as it contributes to covering fixed costs and the remainder contributes

to the profits to be made. If the contribution margin is not adequate to cover the fixed costs, there will be a loss (Boersma *et al.* 2013).

- Based on a fixed unit price of R90.16 for Type A boards the break-even quantity is roughly 19 041 boards per annum. Based on a fixed unit price of R120.76 for Type B boards, the break-even quantity is roughly 18 594 boards per annum.
- The break-even value amount was R1 716 681.68 and R2 245 477.23 for Type A and Type B respectively, which is the rand amount of the units sold at the break-even point annually.

The selling prices (SP) for the two board types are justifiable because they exceed the break-even price. This will allow the business to generate a positive return.

The 1 m^2 ceiling board would have a SP of R90.16, therefore working from this generic price to the specific 3 m x 1.2 m x 0.004 m boards which could be a potential replacement for the gypsum boards, the production costs come down when producing the longer ceiling boards. This is evident since the cost of producing one unit (break-even price) is R81.11 for Type A boards and R110.02 for Type B boards yet it is three times bigger the generic size.

Based on the break-even analysis results, Type B boards reach break-even point before Type A boards and yields a break-even value amount higher than Type A boards. The break-even quantity mean that the production will run for approximately ten months before it can start making a profit because 1 820 boards are produced monthly. Therefore, Type B boards could be pursued.

5.4.3.6 A budgeted statement of profit or loss and other comprehensive income

A budgeted statement of profit or loss and other comprehensive income will be used to evaluate the project's profitability. This contains all of the line items found in a normal income statement, except that it is a projection of what the income statement will look like during future budget periods (Accounting Tools 2019). It is extremely useful for evaluating whether the projected financial results of a company appear to be reasonable. It also gives an essential viewpoint on the projects business financial health or profitability (Ittelson 2009).

From the budgeted statement of profit or loss and other comprehensive income it is evident that the proposed WPC ceiling boards at Kayamandi are financially viable based on the key assumptions mentioned.

According to the calculated budgeted statement of profit or loss and other comprehensive income, Type A boards sold at R90.16 (higher than the R81.11 break-even price) would yield revenue of R1 969 031.45 and R2 250 321.66 in year 1 and 2 respectively. The earnings before interest and tax (EBIT), which are calculated as the difference between revenue and expenses, excluding tax and interest can be used as an indicator to determine a company's profitability (Investopedia 2019). The EBIT amount was R785 771.79 and R983 301.61 for year 1 and 2 respectively for Type A. The annual loan repayment has been accounted for and the net profit after tax is R151 222.48 and R293 443.95 for year 1 and 2 respectively. Type B boards sold at R120.76 (higher than the R110.02 break-even price) would yield revenue of R2 637 475.68 and R3 0142 57.92 in year 1 and 2 respectively, an EBIT amount of R840 393.76 and R1 015 159.71 for year 1 and 2 respectively. The annual loan repayment has also been accounted for and the net profit after tax is R190 550.30 and R316 381.79 for year 1 and 2 respectively (

Table 17).

Both product types are profitable and could be pursued. However, based on the estimated net profits after tax, Type B boards has the highest profits in year 1 and 2 and is recommended for commercialization. Appendix 4A and 4B show detailed calculations of the budgeted statement of profit or loss for Type A and Type B boards respectively.

Table 17: A budgeted statement of profit or loss and other comprehensive income for Type A and Type B boards

Type A boards (1 m x 1 m x 0.004 m)			
		Year 2020	Year 2021
	Notes	Amount (R)	Amount (R)
Revenue	1	**1 969 031.45**	**2 250 321.66**
Cost of goods sold	2	937 634.02	1 005 917.41
Gross profit		1 031 397.43	1 244 404.25
Administration and selling expenses			
Marketing costs	3	1 000.00	1 045.00
Rent of administration office	4	24 000.00	26 400.00
Admin staff	5	36 000.00	38 160.00
Manager		180 000.00	190 800.00
Depreciation of Admin equipment	6	1 025.64	1 025.64
Telephone bill	7	3 600.00	3 672.00
EBIT		**785 771.79**	**983 301.61**
Finance costs (loan repayment)	8	575 740.56	575 740.56
Net profit before tax		210 031.22	407 561.04
Taxation	9	58 808.74	114 117.09
Net profit after tax		**151 222.48**	**293 443.95**
Type B boards (3 m x 1.2 m x 0.004 m)			
		Year 2020	Year 2021
	Notes	Amount (R)	Amount (R)

Revenue	1	**2 637 475.68**	**3 014 257.92**
Cost of goods sold	2	1 551 456.28	1 737 995.56
Gross profit		1 086 019.40	1 276 262.35
Administration and selling expenses			
Marketing costs	3	1 000.00	1 045.00
Rent of administration office	4	24 000.00	26 400.00
Admin staff	5	36 000.00	38 160.00
Manager		180 000.00	190 800.00
Depreciation of Admin equipment	6	1 025.64	1 025.64
Telephone bill	7	3 600.00	3 672.00
EBIT		840 393.76	1 015 159.71
Finance costs (loan repayment)	8	575 740.56	575 740.56
Net profit before tax		264 653.19	439 419.15
Taxation	9	74 102.89	123 037.36
Net profit after tax		190 550.30	316 381.79

Although the selling prices for year 2 in both business models did not increase, the business still managed to make reasonable profits which could be reinvested. This was done to secure a niche market. The notes in the table above are applicable to year 2 when inflating the costs. Note 1 shows the increased revenue caused by a one hour increase in production for year 2 to beat inflation. Note 2 is a list of direct manufacturing costs. Note 3 shows that marketing costs will increase by 4.5%. Note 5 shows a 6% salary increase for the employees. Note 7 is a slight 2% telephone increase cost. Note 8 in the appendices show interest on loan, but for practical purposes the total annual loan repayment was included in the budgeted statement to evaluate if the business could settle the loan repayment and still make profits and Note 9 shows the 28% corporate tax calculation.

5.4.3.6 Net present value

The Net Present Value (NPV) is a valuation method used to calculate the value, which will be added to the business when pursuing a particular project. This is done by assessing all future cash flow, which will be received over the entire investment life of the project, discounting it to the present and then netting off (subtracting) the initial investment. The cash flow needs to be discounted to account for the time value of money (CFI 2019). 'Discounting' refers to the process of representing future monetary value in today's terms (Osteryoung *et al.* 1997). The rate used to discount cash flow is the weighted average cost of capital after tax cost of debt as that is the only cost of capital in this small business context. The NPV was calculated using the following formula:

$$NPV = \sum_{t=1}^{T} \frac{Z_t}{(1-i)^t} - X_0$$

(3)

Where Z = Cash inflow, *i* = Discount rate and X_0 = Initial investment

The net present value analysis was conducted by assuming the following:

- For the purposes of the NPV calculations, an initial investment of R2 992 029.82 was used. This value only considers the costs of purchasing the machinery required for the processing plant and not the full loan.
- A corporate tax rate of 28%, at the time of writing as required by SARS (2019).
- A discount rate of 7.38%. Note: The current prime lending rate as of the time writing had a benchmark of 10% set by South African Reserve Bank (2019) and the majority of financial institutions opt for 10.25%, therefore this is the cost of capital. When discounting cash flows the after tax cost of debt is used hence a discount rate of 7.38% which is calculated as 10.25 %*(1-0.28).
- A price inflation of 4.5% as per (StatsSA 2019) at the time of writing.

The net cash flow was calculated as the difference between the revenue and sum of cash outflows and the present value cash flow was calculated as the product of the after tax cash flow and discount factor. Finally the NPV was calculated as the difference of the sum of present value cash flow and the initial investment. From the analysis of the ten year projection it is clear that the NPV for the ceiling board business made from WPC is positive. Type A boards yield an NPV of R3 350 955.24 and Type B boards yield an NPV of R3 559 512.53 (Table 18). Appendix 5A and 5B show detailed NPV calculations for Type A and Type B boards respectively.

Table 18: NPV summary for Type A and B boards over a 10 year period

Type A boards	Cash flow
Present value cash flows (Year 1 to 10)	R6 342 985.06
Initial Investment	(R2 992 029.82)
Net present value	R3 350 955.24
Type B boards	Cash flow
Present value cash flows (Year 1 to 10)	R6 551 542.35
Initial Investment	(R2 992 029.82)
Net present value	R3 559 512.53

The NPV decision rule stipulates that investments with a positive NPV should be accepted and a project with a negative NPV should not be followed (Ittelson 2009). In addition, the Rand value for the cost of capital (interest on loan and loan repayments) is not included in the calculation of the NPV, as this value is already accounted for when discounting cash flows using the after tax cost of debt (Ardalan 2012). Thus, it can be concluded that the WPC ceiling board enterprise is financially viable taking into consideration the assumptions made in the financial analysis. Appendix 5A and 5B show detailed calculations of the NPV for Type A and Type B boards respectively for ten financial years.

A general rule of thumb is that, when multiple proposed investments have a positive NPV, the investment yielding the highest NPV should be the one pursued (Boersma *et al.* 2013). Therefore, Type B boards would be pursed since it would add more value to the small business. In conclusion, the NPV results, show that both product types have a positive NPV therefore could be pursued, but Type B boards would be first preference since that yielded the highest NPV.

5.4.3.7 Sensitivity analysis

A sensitivity analysis can be done by changing one variable at a time, while keeping the other values constant (Osteryoung *et al.* 1997). This determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions (Investopedia 2019). It allows for forecasting in case the business model changes or product changes.

In this hypothetical small business, the sensitivity analysis was done by determining how sensitive the break-even point is to a change in the selling price (SP) per unit, plastic or biomass costs per unit and six different scenarios were conducted (Table 19). The initial break-even points for the boards were 19 041 units and 18 594 units for Type A and B boards, respectively per annum in the year of inception. Scenario 1 shows a 10% SP decrease on the Type A and Type B boards. This resulted to an increase in the break-even points for both board types. Type A break-even point would result to 21 828 units (14.64% increase on initial break-even point) and Type B break-even point changed to 22 323 units (20.05% increase on initial break-even point). These break-even point increases are expected because reducing the SP reduces the contribution margin, which means the business would have to produce more units to cover production costs in order to break-even. This scenario is unfavourable since the decreased selling prices are close to the initial break-even prices.

Scenario 2 shows a 10% increase on only the SP, whereby Type A would have an SP of R99.17 and Type B a SP of R132.84. This resulted in a reduction of the forecast break-even points for both board types. Type A forecast break-even point would be 16 884 units (11.33% decrease) and 15 933 units (14.31% decrease). This scenario is favourable for the business model since an increase in the SP would increase the contribution margin and ensure that there are sufficient funds to cover production costs and generate profit while the costs of production remain constant. Comparing scenario 1 and 2, one can already conclude that the change in selling prices prove that the break-even points are highly sensitive to the change in SP. Scenario 3 is a 10% cost increase on biomass or plastic costs per unit and keeping the SP constant. Type A biomass cost per unit increased to R1.72 and the break-even slightly increased to 19 083 units annually (0.22% increase). The plastic cost per unit for Type A increased to R 10.49 yielding a forecast break-even point of 19 301 units yearly (1.37% increase). This 10% increase had a more negative impact on the increased plastic cost per unit since it is the most costly raw material. The 10% cost increase on the biomass per unit was R6.26, which resulted to a slight increase of 18 742 units for Type B boards (0.80% increase). The increase on plastic cost per unit shifted to R37.38 and resulted to 19 511 units (4.93% increase). The 10% increase in plastic cost for Type B was also not favourable like in Type A since plastic costs more in the production process. Therefore, an increase in plastic costs for both boards is unfavourable as this increases production costs, decreases contribution margin and pushes the break-even point up with no counter effect from the SP since it stays constant.

Scenario 4 is the opposite of scenario 3, whereby this scenario shows a 10% cost decrease on biomass or plastic costs per unit and the SP is unchanged. In terms of Type A, when the biomass cost per unit is decreased to R1.41, the forecast break-even would change to 18 998 units (0.23% decrease) and if the plastic decreased to R8.58, the new break-even point would be 18 787 units (1.33% decrease). With regards to Type B, a decrease cost in biomass would result in 18 449 units (0.78% decrease) and a plastic cost reduction would result in 17 759 units (4.49% decrease). These decreases in break-even points are expected as the cost of production would lessen, contribution margin increases, thereby allowing break-even to occur sooner. The reduction of plastic cost per unit in both board types was more favourable since it costs more in the production process and its decrease in costs results to a lower break-even point.

Scenario 5 shows results of a 10% cost increase on raw material and 10% reduced SP. Based on Type A findings, a decreased SP would be R81.14 (almost break-even price) and increased biomass cost per unit would be R1.72 and a combination of the two would result in an increased break-even forecast point of 21 884 units (15% increase). An increased plastic cost per unit would be R10.49 and a combination with a reduced SP would yield in an increased break-even forecast point of 22 172 units (16% increase). In terms of Type B, a decreased SP would be R108.69 which is lower than the break-even price and increased biomass cost per unit would be R6.26 and a combination of the two to determine the forecast break-even point was 22 536 units (21% increase). An increased plastic cost per unit would be R37.38 resulting to an increased break-even point of 23 658 units (27% increase). Overall, this is a highly unlikely scenario in a business setting and unfavourable. An increase in production costs and reduced contribution margin (caused by a reduced SP) will increase forecast break-even in order to sell more units to be sold to cover production costs and accumulate profits. Type B has higher forecast break-even points because more raw material is used for production translating to high costs of production compared to Type A.

Scenario 6 shows results of a more probable business case, whereby there would be a 10% biomass or plastic increase cost per unit and an increased SP. Type A selling price would increase to R99.17 and the biomass cost per unit would increase to R1.72 resulting in a forecast break-even point of 16 918 (11% decrease). An increased plastic cost per unit would be R10.49 which would yield 17 089 units (10% decrease). Type B increased SP would be R132.84 and the biomass cost per unit would increase to R6.26 yielding to a forecast break-even point of 16 041 units per annum (14% decrease). An increased plastic cost per unit (R 37.38) with an increased SP would result to 16 601 units (11% decrease). The combination between the increase in individual raw material cost per unit and an increased SP show that an upward change in the break-even point which is caused by an increase in the biomass or plastic cost is counteracted by the downward effect in the break-even point caused by an increase in SP. The total variable costs slightly increase but the contribution margin increases the most, resulting to a low break-even point.

Scenario 6 favours an increase in the cost of biomass per unit with a combination of an increase in SP rather than an increase in plastic since biomass would still cost less than plastic even when the cost is increased. The increase in biomass cost per unit has minimum effect on the forecast break-even point and is also assisted by the increase in SP increase thereby allowing break-even to be reached sooner. The combination between an increase in plastic cost per unit and increase in SP would mean that there would be higher costs of production and less contribution margin compared to biomass cost per unit.

Table 19: Sensitivity analysis for Type A and B boards, showing the effect of a 10% decrease on the selling price, variable cost per unit and annual fixed costs

Type A boards (1 m x 1 m x 0.004 m)				
Initial Type A breakeven point per annum				**19 041**
Scenario 1				
Selling price per unit	Original scenario SP	10% decrease in SP only	Forecast break-even point	% change
	R 90.16	R 81.14	21 828	14.64%
Scenario 2				
Selling price per unit	Original scenario	10% increase in SP only	Forecast break-even point	% change
	R 90.16	R 99.17	16 884	-11.33%
Scenario 3				
	Original scenario	10% cost increase and same selling price	Forecast break-even point	% change
Selling price/unit	R 90.16	R 90.16		
Biomass cost/unit	R 1.57	R 1.72	19 083	0.22%
Plastic cost/unit	R 9.54	R 10.49	19 301	1.37%
Scenario 4				
	Original scenario	10% cost decrease and same selling price	Forecast break-even point	% change
Selling price/unit	R 90.16	R 90.16		
Biomass cost/unit	R 1.57	R 1.41	18 998	-0.23%
Plastic cost/unit	R 9.54	R 8.58	18 787	-1.33%
Scenario 5 (worst case)				
	Original scenario	10% cost increase but SP decrease	Forecast break-even point	% change
Selling price/unit	R 90.16	R 81.14		
Biomass cost/unit	R 1.57	R 1.72	21 884	15%
Plastic cost/unit	R 9.98	R 10.49	22 172	16%
Scenario 6 (probable case)				
	Original scenario	10% cost increase and SP increase	Forecast break-even point	% change
Selling price/unit	R 90.16	R 99.17		
Biomass cost/unit	R 1.57	R 1.72	16 918	-11%
Plastic cost/unit	R 9.54	R 10.49	17 089	-10%
Type B (3 m x 1.2 m x 0.004 m)				
Initial Type B break-even point per annum				**18 594**
Scenario 1				
Selling price/unit	Original scenario	10% decrease in SP only	Forecast break-even point	% change
	R 120.76	R 108.69	22 323	20.05%
Scenario 2				
Selling price/unit	Original scenario	10% increase in SP only	Forecast break-even point	% change
	R 120.76	R 132.84	15 933	-14.31%

Scenario 3				
	Original scenario	10% cost increase and same selling price	Forecast break-even point	% change
Selling price/unit	R 120.76	R 120.76		
Biomass cost/unit	R 5.69	R 6.26	18 742	0.80%
Plastic cost/unit	R 33.98	R 37.38	19 511	4.93%
Scenario 4				
	Original scenario	10% cost decrease and same selling price	Forecast break-even point	% change
Selling price/unit	R 120.76	R 120.76		
Biomass cost/unit	R 5.69	R 5.12	18 449	-0.78%
Plastic cost/unit	R 33.98	R 30.58	17 759	-4.49%
Scenario 5 (worst case)				
	Original scenario	10% cost increase but SP decrease	Forecast break-even point	% change
Selling price/unit	R 120.76	R 108.69		
Biomass/unit	R 5.69	R 6.26	22 536	21%
Plastic/unit	R 33.98	R 37.38	23 658	27%
Scenario 6 (probable case)				
	Original scenario	10% cost increase and SP increase	Forecast break-even point	% change
Selling price/unit	R 120.76	R 132.84		
Biomass/unit	R 5.69	R 6.26	16 041	-14%
Plastic/unit	R 33.98	R 37.38	16 601	-11%

Type A boards produced in the same production line proved to run under capacity, for some machines, therefore the cost of production was high. The Type A boards proved to be impractical for the consumers, because one 42 m^2 house would require forty two ceiling boards instead of the thirteen boards currently required when using the 3 m x 1.2 m boards. The 1 m x 1 m x 0.004 m boards having a SP of R90.16 would mean that R3 786.72 would have to be budgeted for ceiling if Type A boards would be implemented. When considering the current budget for ceiling boards for RDP houses, these Type A boards dimensions are impractical and too expensive to be implemented for the low-cost housing, but the Type B boards could potentially replace the currently used gypsum boards. The Type B boards would have the same dimensions as the ceiling boards currently being used and the SP is well within the range of what is in the market, if not more affordable considering the better features.

The WPC ceiling boards have better strength properties, appealing, bio-based and are a sustainable alternative to gypsu^{m} boards. A single gypsum ceiling board currently used, when inflated to allow the passage of time would cost R125.41 (excluding VAT) in 2020 translating to R1 630.33 that would have to be budgeted since thirteen boards are required per 42 m^2 house. If the proposed Type B WPC ceiling boards could be implemented at R120.76 per board, it would translate to R1 569.88 for ceiling per house. The implementation of WPC ceiling boards could be an affordable alternative to the current gypsum boards. This concludes that the 3 m x 1.2 m x 0.004 m WPC ceiling boards are feasible.

6 Conclusions and Recommendations

The government is under pressure to address environmental, economic and social challenges in the country. The increase in population has resulted in an increase in pollution, increased urbanization rate (more people are moving to the cities), social housing backlog, high unemployment rate and some environmental challenges include plastic pollution and the infestation of IAPs. Sustainable and innovative solutions are vital to address these issues.

IAPs cover approximately 10 million ha of South African land and threaten the ecosystem they invade (Meijninger and Jarmain 2014). They out-compete natural vegetation, consume large amounts of water and reduce the biodiversity of the area they infest. Billions of Rands have been invested in the WfW Programme since its inception with aims to eradicate the IAPs (van Wilgen and Wilson 2018). South Africa used approximately 1.88 million t of virgin plastic in 2018 and only 352 000 t was recycled into raw material (PlasticsSA 2019). Plastic packaging has a short lifespan yet is responsible for the largest plastic use (Giacovelli 2018). Majority of plastic are not biodegradable and remain in the environment for centuries (Bashir 2013). This is hazardous because most plastic matter get transported either by wind or rain into water sources or other land spaces and wildlife ingest or get entangled with the material presuming it is edible.

To address these environmental issues WfW has created awareness on IAPs and launched the VAI to use the cleared biomass for valuable products. In addition, numerous organizations have created awareness on plastic pollution and the importance of recycling. Incorporating these undesirable raw material from the environment (*A. saligna* and recycled LLDPE) to produce WPC material can be economically and environmentally beneficial.

The general objective of the study was to assess the feasibility of starting a small hypothetical WPC enterprise producing building material for low cost housing in South Africa and the specific objective was to determine the financial perspective of producing WPCs made from invasive trees and recycled LLDPE plastic for RDP houses. The WPC sample boards produced and tested exceeded the benchmark of the gypsum ceiling board mechanical properties

At the time of writing, the official National unemployment rate was 29% (StatsSA 2019) and encouraging small business development is beneficial for the country's economy since that could create job opportunities and develop new skills for unemployed people. The establishment of this small business would have benefits, such as introducing an innovative bio-based building material for social housing, it would not be as capital intensive as starting a big business, it would allow for competitive markets, it would utilize local waste material deemed as undesirable and most importantly it will improve the socio-economic status of people by contributing to job creation initiatives by training and employing people to produce WPC ceiling boards for low cost buildings. Although, numerous jobs are already created in the business stream, such as within the WfW programme and the recycling plastic industry, small businesses do make a difference and when the business expands as more jobs are created. In addition, small business development empowers people with new skills through job training.

The social housing backlog in South Africa implies that the government is not able to meet the housing needs of the rising population. Furthermore, the housing budget has remained unchanged at approximately R120 000 per house for the last six years (DHS 2013). The government is under pressure to meet housing needs for the low income earners who cannot afford to buy their own homes and the medium-class earners who earn too much to qualify for RDP houses and too little to qualify for bank loans. Therefore, the NHBRC has to look into finding new unconventional building systems that are safe for people to live in and ensure that they are safe for the people to live in them. If the WPC project would be SABS approved and accepted, the NHBRC would have to inspect and do quality assurance checks in order for building contractors to use the WPC boards. Based on the fact that 86% of the respondents in Kayamandi complained about the weak and mouldy walls, wall panels could be introduced. Defective walls in RDP houses are a common problem across all provinces, as Western Cape, Free State and KwaZulu-Natal RDP occupants were the least satisfied in a General Household Survey conducted by StatsSA (2018).

The newly constructed RDP houses walls are made from concrete blocks, the ceiling is made from gypsum, steel is used for the window and door frames, wood is used for the doors and corrugated iron sheets or clay tiles are used for roofing. Incorporating WPC material as a building material would promote sustainable building construction and reduce heterogeneous raw material in the environment whilst ensuring the longevity of the building since WPC have desirable mechanical properties.

If WPC wall panels would be introduced, they would have to compete with the “smart RDP houses” made from light-weight steel and mortar applications which have had a pilot project in North West (AV Light Steel 2019) and inspected by the NHBRC.

The results from the financial analysis showed that a small WPC ceiling business enterprise is feasible, taking into consideration the set of business assumptions mentioned in Chapter 5 used to perform the financial analyses. The WPC ceiling application is not as common as wall cladding or decking both locally and on a global perspective, however there are WPC ceiling boards sold as ceiling tiles (500 mm x 500 mm) or square metre boards in overseas markets.

Their selling point include that they are environmentally friendly, fireproof and have good acoustical insulation properties. In addition, they can come in various colours, as seen in the WPCs sample boards. The majority of these WPC ceiling boards are found in the hospitality industry, such as hotels or luxury houses.

Presuming that the projected 21 840 boards per annum are manufactured and sold, the company would have sufficient funds to repay the loan for the ten-year period as can be seen in Page 61 on the amortization table (Table 13) and the residual could be reinvested in the business. Type A boards were standardized 1 m^2 boards and Type B were 3 m x 1.2 m boards, which have the dimensions of the ceiling boards already in the market.

An approximate ten months' worth of production would have to be done to break even for both board types. The contribution margin was sufficient to cover fixed costs and contribute to the project's profits. The mark-up percentages on cost of goods sold ensured that the selling prices per unit exceeded break-even prices, which allowed the business to generate some profit. Based on the break-even analysis results, the Type B WPC ceiling boards are recommended for the establishment of the small business, because they break-even sooner than Type A boards, have a higher selling price and break-even value.

The budgeted statement of profit or loss and other comprehensive income shows the net profit or loss of a business (Cilliers *et al.* 1996). Based on the assumptions made, the product resulted in positive net profits after taxation for the first two years of inception for both board types, even with the same SP in order to establish a niche market. This indicates that the project could be profitable and could be pursued. Type B boards yielded higher net profits for both years therefore are recommended for business development.

Given that the goal of any business is to increase in value, a project with a positive NPV should be accepted and pursued (Firer *et al.* 2008). The NPVs for both board types were positive and as a rule of thumb the investment with the highest NPV would have to be pursued (Boersma *et al.* 2013). Type B boards would have to be pursued rather than Type A boards, since that would yield the highest NPV. A positive NPV indicates that the project will add value and therefore feasible. This WPC ceiling board investment could be pursued because the NPV is positive.

As suggested by Osteryoung *et al.* (1997) one input cost type needs to be changed and the others kept constant to determine the financial sensitivity to cost and production variables. In the project's context, the SP per unit and variable costs per unit (biomass or plastic) were subjected to six various scenarios to determine the effects they have on the initial break-even points. Scenario 1 (decrease in SP only) had an unfavourable impact on the initial break-even points for the two board types. This would be expected because the contribution margin would ultimately be reduced. Scenario 5 (variable cost increase and reduced SP) also had an unfavourable impact which was done to stress test the assumptions and thereby implying that the costs of production (raw material) would be high, contribution margin would decrease and the SP would be too low to cover the expenses and generate profits.

The most favourable case would be scenario 2 (increase in SP only), whereby there would be sufficient funds to settle production costs and have a surplus generating profits thereby reaching break-even sooner as production costs remain unchanged. A more realistic case is scenario 6 (increase in raw material and increase in SP) as this prepares the business for inflation in future, the forecast break-even points is lower. The counter effect between increased variable costs and increased SP is balanced by the high contribution margin. It can be concluded from scenario 4 (reduction in individual variable costs) that decreasing plastic costs is more beneficial as that is the most expensive raw material, this would imply that there would be cheaper plastic costs leading to low break-even points.

Other than the acquisition of sufficient start-up capital, the small business would be subjected to pay a 28% corporate tax and implement a 15% VAT on the WPC boards leading to increased purchasing price which have to compete with established businesses. The Type B VAT inclusive price would be R138.88 which would still be lower than the R144.29 VAT included gypsum boards currently used. The implementation of WPC ceiling boards would be a more sustainable and affordable alternative to gypsum boards. Its VAT excluded price which is what appears on the financial books of the business is adequate in running the production line, pay mandatory corporate tax and still repay the ten-year loan. Once the loan is paid in full, the business would be in a position to expand even more and generate surplus profit.

In conclusion, this proposed WPC project is feasible and could be pursued. IAPs are a threat to the ecosystem and should be eradicated, plastic pollution is undesirable and these two unfavourable resources can be used to produce WPCs that could contribute to the socio-economic development of previously disadvantaged communities. The housing budget needs to be revised to reduce the number of poorly built RDP houses.

Standards for this innovative bio-based material need to be reviewed, since it is gaining traction. Initial financial support would be needed in order to make this project successful, especially because the project is intended for the previously disadvantaged communities. The project is viable because the break-even point is met within ten months, the budgeted statement of profit or loss and other comprehensive income show positive estimated net profits after taxation in the first two years of inception and the NPV is positive.

Recommendations can be summarized as:

- Based on the questionnaires in Kayamandi, the biggest infrastructural defect in RDP houses are the mouldy walls and poor acoustic and thermal insulation. Therefore, wall panels would be a great way to inhibit the permeable concrete walls from absorbing the rain water, reduce the noise levels between the rooms and regulate the room temperatures.
- Low technology, custom made machinery that has adequate throughput suitable for production should be made by local companies to eliminate shipping costs and exorbitant purchasing prices from overseas suppliers.
- The proposed wall panels will have to be SABS approved, then pitched to Government bodies such as DHS and DEA as an unconventional way of building low cost houses to address issues of the defective walls. A pilot project would have to be conducted in order to evaluate the qualities. The WPC wall panels could be viewed as part of the VAI and having a positive social impact by creating jobs.
- Other types of biomass could be tested to replace *A. saligna*, once these trees are eradicated.
- Other municipalities in rural areas could implement recycling initiatives, like the Swop shop in the Kayamandi Township in Stellenbosch.
- The small business could form a strategic partnership (vertical partnership) with its plastic supplier (the buy-back) which would reduce problems in the supply chain and ensure the WPC business qualifies for low plastic prices in exchange for a long-term business agreement.
- Another way to ensure lower plastic costs would be that the small business could collect its own plastic waste and make arrangements with the buy-back factory to buy recycled plastic at discounted prices to reduce the overpriced purchasing price, considering that the plastic cost more than the biomass.

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Appendices

Appendix 1: Detailed costs for constructing one RDP house

Qty	Item #	Description	Unit Price		Discount	Line Total	
Foundation							
3.00	SAND1	Sand per cubic metre building	R	198.00		R	594.00
4.00	RMC20	Readymix concrete 20mpa per cub	R	1 165.50		R	4 662.00
4.50	RMC10-19	Readymix concrete 10mpa per cub	R	1 060.50		R	4 772.25
1.00	STONE1	Stone per cubic metre	R	473.00		R	473.00
3.00	BF110	Brickforce 110mm x 2.8mm x 20m	R	36.87		R	110.61
200.00	160226A	Blocks 140mm x 190mm x 390mm	R	7.41		R	1 482.00
7.00	100	Cement 50kg bag	R	62.28		R	435.96
4.00	MESH193	Mesh 193 (slab) 6.0m x 2.4m	R	289.20		R	1 156.80
0.50	BU330	Black u/lay sabs 3.0m x 30m x 250mic	R	545.00		R	272.50
						R	**13 959.12**
Wallplate							
8.00	SAND1	Sand per cubic metre building	R	198.00		R	1 584.00
900.00	160226A	Blocks 140mm x 190mm x 390mm	R	7.41		R	6 669.00
350.00	160226	Blocks 90mm x 190mm x 390mm	R	5.94		R	2 079.00
75.00	160226A	Blocks 140mm u lintol	R	7.41		R	555.75
18.00	100	Cement 50kg bag	R	62.28		R	1 121.04
8.00	BF110	Brickforce 110mm x 2.8mm x 20m	R	36.87		R	294.96
4.00	160020	Brickforce 75mm x 2.8mm x 20m	R	36.87		R	147.48
5.00	Y10	Y10 steel rod 6.5mm	R	42.00		R	210.00
40.00	160017	Hoop iron per metre	R	6.75		R	270.00
2.00	DF7050/2M	Door frames 70mm x 50mm x 2.0m	R	426.60		R	853.20
3.00	16098	Door frame steel 90mm pbs	R	237.60		R	712.80
1.00	C163/0112	Damp course 150mm x 40m x 250mic	R	55.00		R	55.00
1.00	16050	Lintol 145 x 75 x 3.6m	R	179.96		R	179.96
3.00	Q1	Window Q1 brass range 900 x 1.2	R	465.82		R	1 397.46
1.00	P1	Window P1 brass range 900 x 900	R	443.76		R	443.76
1.00	U1	Window U1 brass range 600 x 900	R	370.21		R	370.21
1.00	C163/0112	Damp course 110mm x 40m x 250mic	R	59.65		R	59.65
6.00	15493	Conduit pipe 20mm x 4m	R	10.99		R	65.94
6.00	FB44	Flush box 4 x 4	R	5.25		R	31.50
5.00	FB42	Flush box 4 x 2	R	4.50		R	22.50
5.00	VENTP	Vent plastic white	R	3.95		R	19.75

5.00	VENTT	Vent plastic terracotta	R	5.25		R	26.25
						R	**17 169.21**
			Roof				
1.00	TRUSSBW	Trusses 42m2 and sundries	R	9 965.33		R	9 965.33
565.00	MA901011	Roof tiles	R	6.71		R	3 791.15
20.00	MA8010011	Roof ridges	R	33.28		R	665.60
0.50	MT225	Malthoid 225mm x 20m x 2ply	R	248.20		R	124.10
1.00	OR1	Red oxide per kg	R	58.75		R	58.75
2.00	NC63	Nails clout 63mm per kg	R	45.37		R	90.74
1.00	ST65	Roof nails per pack 65mm	R	40.00		R	40.00
						R	**14 735.67**
			Completion				
		Door &Window					
2.00	FLBPB	Door FLB Z Braced	R	1 092.50		R	2 185.00
3.00	FLUSH	Door flush 813	R	180.00		R	540.00
3.00	KKLS2LB	Lockset 2 lever sabs	R	60.75		R	182.25
1.00	GLASS1	Glass fit and supply	R	900.00		R	900.00
2.00	KKLS3LB	Lockset 3 lever sabs	R	63.50		R	127.00
2.00	1100535BR	Hinge b/p 100mm with screws	R	17.65		R	35.30
2.00	WB7040-900	Weatherboard 70 x 40	R	58.80		R	117.60
		Electrical					
50.00	15443	Wire T & E 1.5mm per metre	R	5.36		R	268.00
40.00	15444	Wire T & E 2.5mm per metre	R	7.15		R	286.00
1.00	***************	Earth spike 1.2m	R	126.60		R	126.60
1.00	***************	Earth clamp	R	18.75		R	18.75
10.00	***************	Wire green and yellow 10mm p/m	R	16.78		R	167.80
1.00	***************	Wire black 10mm p/m	R	16.78		R	16.78
1.00	***************	Wire red 10mm p/m	R	16.78		R	16.78
5.00	READY	Ready light	R	21.32		R	106.60
2.00	BULK2	Bulk head fitting	R	21.63		R	43.26
2.00	SS120	Switch 1 lever 1way 4x2	R	14.65		R	29.30
2.00	SS220	Switch 2 lever 1way 4x2	R	17.65		R	35.30
6.00	PD44	Switch plug double 4x4	R	29.65		R	177.90
1.00	DB	DB Board complete	R	395.00		R	395.00
7.00	LED5	Energy saver globes	R	11.65		R	81.55
		Ceiling					
13.00	16761G	Rhinoboard 3.0m x 1.2m x 6.4mm	R	109.95		R	1 429.35
22.00	16798G	Rhino cornice 3.0m x 75mm	R	31.20		R	686.40
151.20	3850/PM	Timber 38 x 50 per metre	R	11.44		R	1 729.73
		42 x 3.6 metre lengths					
7.00	ISO50	Isotherm 135mm x 1.2m x 5.0m	R	352.06		R	2 464.42
250.00	ST630	Drywall screws 6 x 30	R	0.11		R	27.50
250.00	DWS6X45	Drywall screw 6 x 45	R	0.15		R	37.50

250.00	ST630	Drywall screws 6 x 30	R	0.11		R	27.50
250.00	DWS6X45	Drywall screw 6 x 45	R	0.15		R	37.50
10.00	1071	H Strip profile 6.4mm x 3.0m	R	19.17		R	191.70
1.00	SAP1044-30	Coverstrip 10 x 44 x 3.0m	R	25.00		R	25.00
1.00	16808	Cretestone 40 kg	R	200.10		R	200.10
3.00	RMC10-19	Readymix concrete 10mpa per cub	R	1 060.50		R	3 181.50
20.00	100	Cement 50kg bag	R	62.28		R	1 245.60
8.00	SAND1	Sand per cubic metre plaster	R	264.00		R	2 112.00
2.00	NW75	Nails wire 75mm per kg	R	16.25		R	32.50
		Plumbing					
2.00	2500	U/G pipe 110mm x 6.0m	R	150.00		R	300.00
3.00	268	U/G bend 110mm x 90 plain	R	24.75		R	74.25
3.00	269	U/G bend 110mm x 45 plain	R	25.65		R	76.95
3.00	270	U/G junction 110mm x 45 plain	R	33.07		R	99.21
1.00	UGH110	U/G gulley head & grit 110mm	R	19.65		R	19.65
1.00	UGG110	U/G gulley trap 110mm	R	40.50		R	40.50
2.00	264R	U/G rodding eye 110mm	R	24.50		R	49.00
1.00	260	U/G single collar 110mm	R	19.57		R	19.57
1.00	271	U/G junction 110mm x 90 plain	R	33.08		R	33.08
1.00	240	S/V vent horn bend 110mm x 95	R	32.40		R	32.40
1.00	201	S/V pipe 40mm x 6.0m	R	51.65		R	51.65
5.00	203	S/V 40mm x 95 bend	R	4.65		R	23.25
3.00	205	S/V 40mm x 95 bend ie	R	5.25		R	15.75
1.00	30068	Vent valve 2way 50mm	R	11.25		R	11.25
1.00	PPL	P Pan low level	R	161.18		R	161.18
1.00	ELF	Cistern low level elf	R	148.75		R	148.75
1.00	TB1	Bung rubber	R	4.08		R	4.08
1.00	TS10	Toilet seat	R	52.02		R	52.02
1.00	252	Pan connector	R	17.65		R	17.65
1.00	200508	Basin tunga	R	153.75		R	153.75
1.00	DB2	Trap basin pvc 32mm	R	21.65		R	21.65
1.00	FIX1	Fixation bolt 10 x 100	R	14.50		R	14.50
1.00	FP5	Waste basin slottered pvc 32mm	R	12.50		R	12.50
1.00	1012870	Sink 915 x 460 seb sit on	R	306.25		R	306.25
1.00	203787	Sink cabinet	R	455.00		R	475.00
1.00	DB3	Trap sink pvc 40mm	R	23.00		R	23.00
1.00	FP3	Waste sink pvc 40mm cp top	R	14.65		R	14.65
1.00	BATH17H	Bath 1.7m with handles	R	810.00		R	810.00
1.00	DB17	Giraffe overflow	R	21.00		R	21.00

1.00	DB11	Trap bath pvc 40mm	R	21.00		R	21.00
1.00	WELD100	PVC weld 100ml	R	13.00		R	13.00
3.00	PT2	Thread tape roll	R	3.65		R	10.95
1.00	FP4	Waste bath pvc 40mm	R	12.50		R	12.50
3.00	PM10	Pillar tap 15mm	R	75.00		R	225.00
3.00	616/1/34L	Ball o stop 15mm with lever	R	23.68		R	71.04
25.00	POL15	Polycop pipe 15mm per metre	R	3.25		R	81.25
3.00	FBC200	Flexible braided connector 200mm	R	14.71		R	44.13
3.00	10XS-15	Conex coupling 15mm c x f	R	12.50		R	37.50
6.00	12XS-15	Conex tee 15mm c x c x c	R	19.57		R	117.42
6.00	4XS-15	Conex elbow 15mm c x c	R	12.50		R	75.00
1.00	1281	Wax pan seal ring	R	15.75		R	15.75
		Painting and finishing					
2.00	OP-20	Hi cover pva white 20lt	R	420.00		R	840.00
1.50	NC-20	Nu cover exterior 20lt	R	545.70		R	818.55
5.00	LSILAW	Painters mate 280ml	R	21.00		R	105.00
1.00	***************	Wood oil 5lt	R	310.80		R	310.80
2.00	SIL	Silicone clear 280ml	R	21.00		R	42.00
2.00	SILW	Silicone white 280ml	R	21.00		R	42.00
0.50	MV5M	Varnish 5lt	R	334.80		R	167.40
0.50	OGG-5	Gloss white 5lt	R	330.60		R	165.30
2.00	CF2	Crackfiller 2kg	R	36.13		R	72.26
2.00	SP100	Sandpaper 100/80/60/40 grit roll	R	11.25		R	22.50
						R	**25 612.91**
				Total Discount			
					Subtotal	R	71 476.91
					Vat	R	10 006.77
		44			Total	R	**81 483.68**

Thank you for your business!

[Street Address], [City, ST ZIP Code] [Phone] [Fax] [E-mail]

Appendix 2: Kayamandi questionnaire

1. How many people can an RDP house accommodate?

- 5
- 6-10
- >10

2. How long have you lived in your house?

3. What are the most common problems?

- Thin internal walls
- Poor sound insulation
- Poor thermal insulation
- Leaking roof

4. Are there any other problems, which are not stated above?

5. Please prioritize the structure that needs more attention (1st, 2nd,3rd)?

- ☐
- ☐
- ☐

6. What improvements would you suggest, based on the question above?

7. What kind of flooring do you prefer?

- WPC flooring
- Ceramic tiles
- Concrete
- No tiles
- No preference

8. Would you be happy if the building contractor used the WPC for your house?

- Yes
- No

9. What additional building structures would you be willing to pay for yourself?

- Wall cladding
- Wooden floorboards or laminated flooring
- A WPC outside stoep
- None of the above

10. If you had a preference from above, how much would you be willing to spend?

- R3 500-R4 000 ceramic tiles
- R5 000- R6 000 WPC or laminated floors
- R400.00- R1 500.00 per square metre for wall cladding

Appendix 3A: Historical clearing costs from the Flower Valley Study spreadsheet by Shuttleworth and Ackerman (2009) inflated using PPI

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019					
										Jan	Feb	March	April	May	June
Rate %	16.8	3.4	4.1	2.6	5.3	4.7	16.4	0.4	1.4	-3	-2.2	-0.4	0.3	-3	-1.9
Inflated costs (R)	7 963.42	8 234.18	8 571.78	8 794.65	9 260.76	9 696.02	11 286.17	11 331.31	11 489.95	11 145.25	10 900.06	10 856.46	10 889.03	10 562.36	10 361.67
										The operation cost per ha					**R10 785.80**

Appendix 3B: Historical invoiced transport costs for IAPs harvesting feasibility study by Mugido *et al.* (2014)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019					
										Jan	Feb	March	April	May	June
Rate %	16.8	3.4	4.1	2.6	5.3	4.7	16.4	0.4	1.4	-3	-2.2	-0.4	0.3	-3	-1.9
Inflated costs (R)	3 607.95	3 730.62	3 883.58	3 984.55	4 195.73	4 392.93	5 113.37	5 133.83	5 205.70	5 049.53	4 938.44	4 918.68	4 933.44	4 785.44	4 694.51
										Transport per ha					**R 4 886.67**

Procurement costs for 30 t per hectare	
Harvesting and extraction costs (R/ha)	10 785.80
Transport costs (R/ha)	4 887.67
Total biomass (R/ha)	15 672.48
Total biomass cost per kg (R/kg)	**0.52**

Appendix 4A: Notes for the budgeted income statement for Type A boards

Note 1: Revenue						
	Units	**Number of units**	**Price per unit (R)**	**Total (R)**		
Ceiling boards(Year 2020)	sqm	21 840	90.16	1 969 031.45		
Ceiling boards(Year 2021)	sqm	24 960	90.16	2 250 321.66		
Note 2: Cost of goods sold						
Year 2020					Year 2021	
	Units	**Period**	**Monthly costs (R)**	**Total (R)**	**4.5% increase**	**Total (R)**
Raw material					**0.045**	
Biomass	kg	12	2 848.38	34 180.54		40 765.87
Recycled plastics	kg	12	16 560.00	198 720.00		23 7006.00
Transport for recycled plastics	L	2	400.00	800.00	36.00	836.00
Direct labour	2 workshop employees	12	5 760.00	69 120.00	3 110.40	72 230.40
Manufacturing overheads						
(i) Rent	monthly	12	10 000.00	120 000.00	5 400.00	125 400.00
(ii) Indirect labour	1 Cleaner	12	2 000.00	24 000.00	1 080.00	25 080.00
(iii) Depreciation on chipper	monthly	12	375.00	4 500.00		4 500.00
(iv) Depreciation on hammer mill	monthly	12	860.92	10 331.08		10 331.08
(v) Depreciation on blender	monthly	12	1 135.00	13 620.00		13 620.00
(vi) Depreciation on hot presser	monthly	12	13 001.20	156 014.40		156 014.40
(vii) Consumables	monthly	12	200.00	2 400.00	108.00	2 508.00
(viii) Insurance	monthly	12	15 000.00	180 000.00	8 100.00	188 100.00
(ix) Maintenance and repairs	monthly	12	1 000.00	12 000.00	540.00	12 540.00
(x) Electricity	kW	12	8 729.00	104 748.00	4 713.66	109 461.66
(xi) Water	L	12	600.00	7 200.00	324.00	7 524.00
				937 634.02		1 005 917.41

Note 3: Marketing costs						
Advertising (Year 2020)				1 000.00		
Advertising (Year 2021)				1 045.00		
Note 4: Rent of adminisration office						
		Period	**Monthly costs (R)**	**Total (R)**		
Rent expense(Year 2020)		12	2 000.00	24 000.00		
Rent expense(Year 2021)		12	2 200.00	26 400.00		
Note 5: Admin staff and Manager/owner						
		Period	**Monthly costs (R)**	**Total (R)**		
Admin officer(Year 2020)	1 employee	12	3 000.00	36 000.00		
Admin officer(Year 2021)	1 employee	12	3 180.00	38 160.00		
Manager (Year 2020)	1 employee	12	15 000.00	180 000.00		
Manager (Year 2021)	1 employee	12	15 900.00	190 800.00		
Note 6: Depreciation of admin equipment						
		Period	**Monthly costs (R)**	**Total (R)**		
(i) Computer		12	47.99	575.82		
(ii) Printer		12	37.49	449.82		
				1 025.64		
Note 7: Telephone bill						
		Period	**Monthly costs (R)**	**Total (R)**		
Telephone expense (Year 2020)		12	300.00	3 600.00		
Telephone expense (Year 2021)		12	306.00	3 672.00		

Note 8: Finance cost						
				Total (R)		
Loan interest (Year 2020)				358 750.00		
Loan interest (Year 2021)				336 508.47		
Note 9: Taxation						
	Corporate tax rate	**Taxable amount (R)**		**Taxation (R)**		
Corporate tax (Year 2020)	28%	210 031.22		58 808.74		
Corporate tax (Year 2021)	28%	407 561.04		114 117.09		

Appendix4B: Notes for the budgeted income statement for Type B boards

Note 1: Revenue						
	Units	**Number of units**	**Price per unit (R)**	**Total (R)**		
Ceiling boards(Year 2020)	sqm	21 840	120.76	2 637 475.68		
Ceiling boards(Year 2021)	sqm	24 960	120.76	3 014 257.92		
Note 2: Cost of goods sold						
Year 2020					Year 2021	
	Units	**Period**	**Monthly costs (R)**	**Total (R)**	**4.5% increase**	**Total (R)**
Raw material					**0.045**	
Biomass	kg	12	10 350.76	124 209.07		148 341.12
Recycled plastics	kg	12	59 439.74	713 276.93		851 856.45
Transport for recycled plastics	kg	6	400.00	2 400.00	108.00	2 508.00
Direct labour	2 workshop employees	12	5 760.00	69 120.00	3 110.40	72 230.40
Manufacturing overheads						

(i) Rent	monthly	12	10 000.00	120 000.00	5 400.00	125 400.00
(ii) Indirect labour	1 Cleaner	12	2 000.00	24 000.00	1 080.00	25 080.00
(iii) Depreciation on chipper	monthly	12	375.00	4 500.00		4 500.00
(iv) Depreciation on hammer mill	monthly	12	860.92	10 331.08		10 331.08
(v) Depreciation on blender	monthly	12	1 135.00	13 620.00		13 620.00
(vi) Depreciation on hot presser	monthly	12	13 001.20	156 014.40		156 014.40
(vii) Consumables	monthly	12	200.00	2 400.00	108.00	2 508.00
(viii) Insurance	monthly	12	15 000.00	180 000.00	8 100.00	188 100.00
(ix) Maintenance and repairs	monthly	12	1 000.00	12 000.00	540.00	12 540.00
(x) Electricity	kW	12	9 365.40	112 384.80	5 057.32	117 442.12
(xi) Water	L	12	600.00	7 200.00	324.00	7 524.00
				1 551 456.28		1 737 995.56
Note 3: Marketing costs						
Advertising (Year 2020)				1 000.00		
Advertising (Year 2021)				1 045.00		
Note 4: Rent of administration office						
		Period	**Monthly costs (R)**	**Total (R)**		
Rent expense(Year 2020)		12	2 000.00	24 000.00		
Rent expense(Year 2021)		12	2 200.00	26 400.00		
Note 5: Admin staff and Manager/owner						
		Period	**Monthly costs (R)**	**Total (R)**		
Admin officer(Year 2020)	1 employee	12	3 000.00	36 000.00		
Admin officer(Year 2021)	1 employee	12	3 180.00	38 160.00		
Manager (Year 2020)	1 employee	12	15 000.00	180 000.00		
Manager (Year 2021)	1 employee	12	15 900.00	190 800.00		

Note 6: Depreciation of admin equipment						
		Period	**Monthly costs (R)**	**Total (R)**		
(i) Computer		12	47.99	575.82		
(ii) Printer		12	37.49	449.82		
				1 025.64		
Note 7: Telephone bill						
		Period	**Monthly costs (R)**	**Total (R)**		
Telephone expense (Year 2020)		12	300.00	3 600.00		
Telephone expense (Year 2021)		12	306.00	3 672.00		
Note 8: Finance cost						
				Total (R)		
Loan interest (Year 2020)				358 750.00		
Loan interest (Year 2021)				336 508.47		
Note 9: Taxation						
	Corporate tax rate	**Taxable amount (R)**		**Taxation (R)**		
Corporate tax (Year 2020)	28%	264 653.19		74 102.89		
Corporate tax (Year 2021)	28%	439 419.15		123 037.36		

Appendix 5A: Net Present Value for Type A boards

Type A boards											
	Year 0 (R)	Year 1 (R)	Year 2 (R)	Year 3 (R)	Year 4 (R)	Year 5 (R)	Year 6 (R)	Year 7 (R)	Year 8 (R)	Year 9 (R)	Year 10 (R)
Initial investment	R 2 992 029.82										
Cash inflows											
Sales		R 1 969 031.45	R 2 250 321.66	R 2 351 586.13	R 2 457 407.51	R 2 567 990.84	R 2 683 550.43	R 2 804 310.20	R 2 930 504.16	R 3 062 376.85	R 3 200 183.81
Cash outflows											
Investment in working capital		R 232 900.54	R 277 771.87	R 290 271.60	R 303 333.82	R 316 983.85	R 331 248.12	R 346 154.28	R 361 731.23	R 378 009.13	R 395 019.54
Rent		R 144 000.00	R 151 800.00	R 166 980.00	R 183 678.00	R 202 045.80	R 222 250.38	R 244 475.42	R 268 922.96	R 295 815.26	R 325 396.78
Salaries		R 309 120.00	R 326 270.40	R 345 846.62	R 366 597.42	R 388 593.27	R 411 908.86	R 436 623.39	R 462 820.80	R 490 590.05	R 520 025.45
Insurance		R 180 000.00	R 188 100.00	R 196 564.50	R 205 409.90	R 214 653.35	R 224 312.75	R 234 406.82	R 244 955.13	R 255 978.11	R 267 497.13
Maintenance		R 12 000.00	R 12 540.00	R 13 104.30	R 13 693.99	R 14 310.22	R 14 954.18	R 15 627.12	R 16 330.34	R 17 065.21	R 17 833.14
Utility bills		R 111 948.00	R 116 985.66	R 122 250.01	R 127 751.27	R 133 500.07	R 139 507.58	R 145 785.42	R 152 345.76	R 159 201.32	R 166 365.38
Consumables		R 2 400.00	R 2 508.00	R 2 620.86	R 2 738.80	R 2 862.04	R 2 990.84	R 3 125.42	R 3 266.07	R 3 413.04	R 3 566.63
Marketing costs		R 1 000.00	R 1 045.00	R 1 092.03	R 1 141.17	R 1 192.52	R 1 246.18	R 1 302.26	R 1 360.86	R 1 422.10	R 1 486.10
Telephone bill		R 3 600.00	R 3 672.00	R 3 745.44	R 3 913.98	R 4 090.11	R 4 274.17	R 4 466.51	R 4 667.50	R 4 877.54	R 5 097.03
Net cashflows		**R 972 062.91**	**R 1 169 628.73**	**R 1 209 110.76**	**R 1 249 149.15**	**R 1 289 759.61**	**R 1 330 857.37**	**R 1 372 343.55**	**R 1 414 103.51**	**R 1 456 005.10**	**R 1 497 896.64**
Tax at 28%		R 272 177.61	R 327 496.04	R 338 551.01	R 349 761.76	R 361 132.69	R 372 640.06	R 384 256.19	R 395 948.98	R 407 681.43	R 419 411.06
After tax cashflows		R 699 885.29	R 842 132.68	R 870 559.75	R 899 387.39	R 928 626.92	R 958 217.31	R 988 087.36	R 1 018 154.53	R 1 048 323.67	R 1 078 485.58
Discount factor		0.93	0.87	0.81	0.75	0.75	0.65	0.61	0.57	0.53	0.49
Present value cashflows		R 651 783.66	R 730 354.52	R 703 118.27	R 676 477.25	R 698 469.86	R 625 062.74	R 600 249.14	R 576 005.33	R 552 312.40	R 529 151.88
Net Present Value	**R 3 350 955.24**										

Appendix 5B: Net Present Value for Type B boards

Type B boards											
	Year 0 (R)	Year 1 (R)	Year 2 (R)	Year 3 (R)	Year 4 (R)	Year 5 (R)	Year 6 (R)	Year 7 (R)	Year 8 (R)	Year 9 (R)	Year 10 (R)
Initial investment	R 2 992 029.82										
Cash inflows											
Sales		R 2 637 475.68	R 3 014 257.92	R 3 149 899.52	R 3 291 645.00	R 3 439 769.03	R 3 594 558.63	R 3 756 313.77	R 3 925 347.89	R 4 101 988.55	R 4 286 578.03
Cash outflows											
Investment in working capital		R 837 486.00	R 1 000 197.56	R 1 045 206.45	R 1 092 240.74	R 1 141 391.58	R 1 192 754.20	R 1 246 428.14	R 1 302 517.40	R 1 361 130.69	R 1 422 381.57
Rent		R 144 000.00	R 151 800.00	R 166 980.00	R 183 678.00	R 202 045.80	R 222 250.38	R 244 475.42	R 268 922.96	R 295 815.26	R 325 396.78
Salaries		R 309 120.00	R 326 270.40	R 345 846.62	R 366 597.42	R 388 593.27	R 411 908.86	R 436 623.39	R 462 820.80	R 490 590.05	R 520 025.45
Insurance		R 180 000.00	R 188 100.00	R 196 564.50	R 205 409.90	R 214 653.35	R 224 312.75	R 234 406.82	R 244 955.13	R 255 978.11	R 267 497.13
Maintenance		R 12 000.00	R 12 540.00	R 13 104.30	R 13 693.99	R 14 310.22	R 14 954.18	R 15 627.12	R 16 330.34	R 17 065.21	R 17 833.14
Utility bills		R 119 584.80	R 124 966.12	R 130 589.59	R 136 466.12	R 142 607.10	R 149 024.42	R 155 730.52	R 162 738.39	R 170 061.62	R 177 714.39
Consumables		R 2 400.00	R 2 508.00	R 2 620.86	R 2 738.80	R 2 862.04	R 2 990.84	R 3 125.42	R 3 266.07	R 3 413.04	R 3 566.63
Marketing costs		R 1 000.00	R 1 045.00	R 1 092.03	R 1 141.17	R 1 192.52	R 1 246.18	R 1 302.26	R 1 360.86	R 1 422.10	R 1 486.10
Telephone bill		R 3 600.00	R 3 672.00	R 3 745.44	R 3 913.98	R 4 090.11	R 4 274.17	R 4 466.51	R 4 667.50	R 4 877.54	R 5 097.03
Net cashflows		**R 1 028 284.88**	**R 1 203 158.84**	**R 1 244 149.73**	**R 1 285 764.87**	**R 1 328 023.03**	**R 1 370 842.65**	**R 1 414 128.17**	**R 1 457 768.44**	**R 1 501 634.94**	**R 1 545 579.83**
Tax at 28%		R 287 919.77	R 336 884.47	R 348 361.92	R 360 014.16	R 371 846.45	R 383 835.94	R 395 955.89	R 408 175.16	R 420 457.78	R 432 762.35
After tax cashflows		R 740 365.11	R 866 274.36	R 895 787.80	R 925 750.70	R 956 176.59	R 987 006.71	R 1 018 172.28	R 1 049 593.28	R 1 081 177.16	R 1 112 817.47
Discount factor		0.93	0.87	0.81	0.75	0.75	0.65	0.61	0.57	0.53	0.49
Present value cashflows		R 689 481.39	R 751 291.82	R 723 494.02	R 696 306.51	R 719 191.43	R 643 842.60	R 618 525.31	R 593 791.32	R 569 621.36	R 545 996.60
Net Present Value	**R 3 559 512.53**										