Barriers and opportunities to the implementation of a zero waste to landfill goal – A platinum mining case study

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PREFACE AND ACKNOWLEDGEMENTS

The class of 2020, little did we know that our world would be turned upside down a month after our first block week when a pandemic took the world by storm. It surely has been a challenging journey in between professional work, block weeks, assignments, dissertation, family time and the pandemic.

Yet here I am in November 2021, ready to submit my dissertation in partial fulfilment of my Masters in Environmental Management, after a successful 1st year in 2020. But none of this would have been possible without the Almighty God and the following important people:

- My wife, Valerie, thanks for all your love, support and understanding even when I lost my personality on occasions when things got too much. You gave me the motivation to keep going. I love you and Jayden!
- My parents, Willem and Jenny, who gave me the opportunity 19 years ago to enrol for tertiary education, without that first step, this next big step would not have been possible. Blessed to have you with me on this journey. I love you and my "crazy" sister, Lynn!
- My leader at work, Hermanus, you "nagged" me for at least 3 years to do my Masters. Now that I am here, I have no regrets, thank you.
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In memory of my mother-in-law, Ina, who succumbed to Covid-19 in June 2021 - This one is for you!

ABSTRACT

According to Kaza *et al* (2018:18), the global amount of waste generated on an annual basis has reached 2.01 billion tonnes, with only 30% being diverted away from landfill through re-use, recycling, composting or incineration. This low percentage of diversion from landfill coupled with the global waste generation figure predicted to increase to 3.4 billion tons by the year 2050, indicates the urgent need for better management of waste by identifying and implementing reduction, re-use and recycling opportunities. From a South African perspective, clear similarities can be drawn with these global waste management trends with about 93 million tons (77%) of the 121 million tons of waste generated per annum being disposed off at landfill (DEA, 2018:20&31).

Landfills have several negative environmental impacts, of which the severity and likelihood will increase as more landfills are established. Some of the main negative environmental impacts associated with landfills include air pollution from waste burning and methane gas release, soil and water pollution caused by seepage from the landfill cells, leachate collection systems, uncontrolled spillages and discharges.

The research aim is built around the following question: What barriers and opportunities may influence the implementation of the zero waste to landfill goal in the platinum mining industry?
The three main objectives are summarised as:

- Identify barriers to zero waste to landfill implementation
- Identify opportunities from the zero waste to landfill implementation
- Identify measures required to bridge the gaps to overcome barriers

The research methodology was based on a case study approach with mixed research methods which included document analysis and semi-structured interviews. The specific case study of a platinum mining company was chosen, as the company in question is leading the current Zero Waste to Landfill (ZW2L) implementation for mining companies in South Africa. The research included all underground and opencast mines, concentrators, smelters and refineries, ensuring that the case study's barriers and opportunities related to its ZW2L approach covered a broad spectrum of individual waste streams. The applicability of the research outcome will therefore not be limited to Anglo American Platinum (AAP) or other mining companies only, but will also be representative of metallurgical related activities.

From the case study it is clear that human related factors was identified as one of the biggest barriers in the ZW2L drive, which was centred around lack of awareness, compliance, responsibility and management support. Financial barriers, mainly due to increased treatment

cost to achieve ZW2L was identified as an important barrier but was ultimately outweighed by the financial opportunities and establishing a positive business case.

The stand-out opportunity identified during this case study was the environmental benefits associated with the ZW2L drive through the elimination of the need for landfill establishment and associated environmental impacts. These positive environmental opportunities coupled with the human factor opportunities, namely positive social impacts were also considered in the overall business case and not limited to the financial business case only. These are all key elements in considering the sustainability of a project like the ZW2L drive.

A positive observation from the case study is that actions to bridge the gaps were identified and successfully implemented to address majority of the barriers identified in driving ZW2L.

Keywords:

- Landfill
- Mining
- Non-mineral
- Platinum
- Waste
- ZW2L

ABBREVIATIONS AND ACRONYMS

3 R's	Reduce, Re-Use and Recycle
AAP	Anglo American Platinum Limited
ACP	Anglo Converter Plant
CEO	Chief Executive Officer
CSR	Corporate Social Responsibility
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
EMA	Environmental Management Agency
EPR	Extended Producer Responsibility
ESG	Environment, Social & Governance
FNASREC	North West University, Faculty of Natural and Agricultural Sciences Ethics Committee
GHG	Green House Gasses
GM	General Manager
GNR	Government Notice Regulation
ISWA	International Solid Waste Association
IWM	Integrated Waste Management
KPI's	Key Performance Indicators
MRD's	Mine Residue Deposits
MTSF	Medium-Term Strategic Framework
NEM: WA	National Environmental Management: Waste Act no 59 of 2008

NWMS	National Waste Management Strategy
NWU	North West University
NDP	National Development Plan
OPSCO	Operations Committee
PMR	Precious Metals Refinery
PPE	Personal Protective Equipment
RDF	Refuse Derived Fuel
RBMR	Rustenburg Base Metals Refiners
SAWIC	South African Waste Information Centre
SDG	Sustainable Development Goal
SDS	Safety Data Sheet
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
ZW2L	Zero Waste To Landfill

KEY DEFINITIONS

Circular economy	An economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles (DEFF, 2020:5).
Composting	A biological process that submits biodegradable waste to anaerobic or aerobic decomposition, and that results in a product that is recovered and can be used to increase soil fertility (UN, 2016).
Corporate Social Responsibility	It is a company's management of its social, environmental and economic aspects in a responsible manner and in line with stakeholder expectations.
Enablon	Software used for Environmental, Health and Safety management systems to capture incidents and record data for tracking key performance indicators.
Extended Producer Responsibility	Means that a producer's responsibility for an identified product is extended to the post -consumer stage of an identified product's life cycle (DFFE, 2021:4)
Green economy	A green economy is defined as low carbon, resource efficient and socially inclusive. In a green economy, growth in employment and income are driven by public and private investment into such economic activities, infrastructure and assets that allow reduced carbon emissions and pollution, enhanced energy and resource efficiency, and prevention of the loss of biodiversity and ecosystem services (UNEP, 2021).
Incineration	The controlled combustion of waste with or without energy recovery (UN, 2016).
Landfilling	Landfilling is final placement of waste at engineered landfill sites (UN, 2016).
Microsoft Teams	Software based management tool utilised for meetings and allows for recording, sharing of video and presentation, chat and sharing of files during remote working.

Mineral waste	The waste portion produced during mining activities after the valuable portion of the ore has been extracted and includes tailings, waste rock and slag
Non-mineral waste	Waste streams being produced which excludes the mineral waste portion. It may include domestic waste, industrial waste for example steel and hazardous waste for example used oil.
Refuse derived fuel	A fuel produced from various types of waste such as municipal solid waste (MSW), industrial waste or commercial waste (DEFF, 2020:5)
Slag stockpiles/dumps	Stockpile of mineral waste resulting from the smelting process. Slag has a glass-like structure.
Smartsheet	Software based management tool that enables team collaboration during remote working
Tailings facility	Dump of mineral waste resulting from the concentrating process in mining. The tailings is a mud-like waste stream dumped in a tailings dam due to high water content.
Waste management hierarchy	Waste management approaches from the most preferred to least preferred management methods from an environmental point of view. The hierarchy is reduce, re-use, recycle, treatment and disposal.
Waste rock dump	After blasting during mining the non-mineral bearing rock (waste rock) is removed and placed on a dump.

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CHAPTER 1 INTRODUCTION

1.1 Background

According to Zaman & Swapan (2016:41), the zero waste philosophy can play an important role in improving waste management on a global scale and describes zero waste to landfill as an emerging philosophy globally (2016:33). Zaman and Swapan suggests that globally, through zero waste to landfill activities, an average person could potentially save around 216 kWh of energy, 0.05 kg GHG and 36 litres of processed water.

The Polokwane Declaration (DEAT, 2001) was signed in September 2001 and according to Taiwo *et al* (2008:52), South Africa committed to achieve a 50% reduction in the amount of waste generated and reduce waste to landfill with 25% by 2012 and thereby supporting the implementation of the waste management hierarchy and reducing waste to landfill.

Anglo American Platinum (AAP), used as the case study in this research, adopted a Zero Waste To Landfill (ZW2L) approach in 2013 which had to be achieved by end 2020.

This chapter will put the rationale for the study into perspective by covering the problem statement, research aim and objectives, scope of the research, associated assumptions and limitations to the scope and concludes with the dissertation structure.

1.2 Problem statement and rationale for the study

According to Kaza *et al* (2018:18), the global amount of waste generated on an annual basis has reached 2.01 billion tonnes, with only 30% being diverted away from landfill through re-use, recycling, composting or incineration and this low percentage of diversion from landfill coupled with the global waste generation figure predicted to increase to 3.4 billion tons by the year 2050. This indicates the urgent need for better management of waste by identifying and implementing reduction, re-use and recycling opportunities. The continuation of landfilling will require new landfills and result in missed opportunities for resource related savings and the creation of job opportunities that can be generated through the circular economy as illustrated by the example in Figure 1-1.

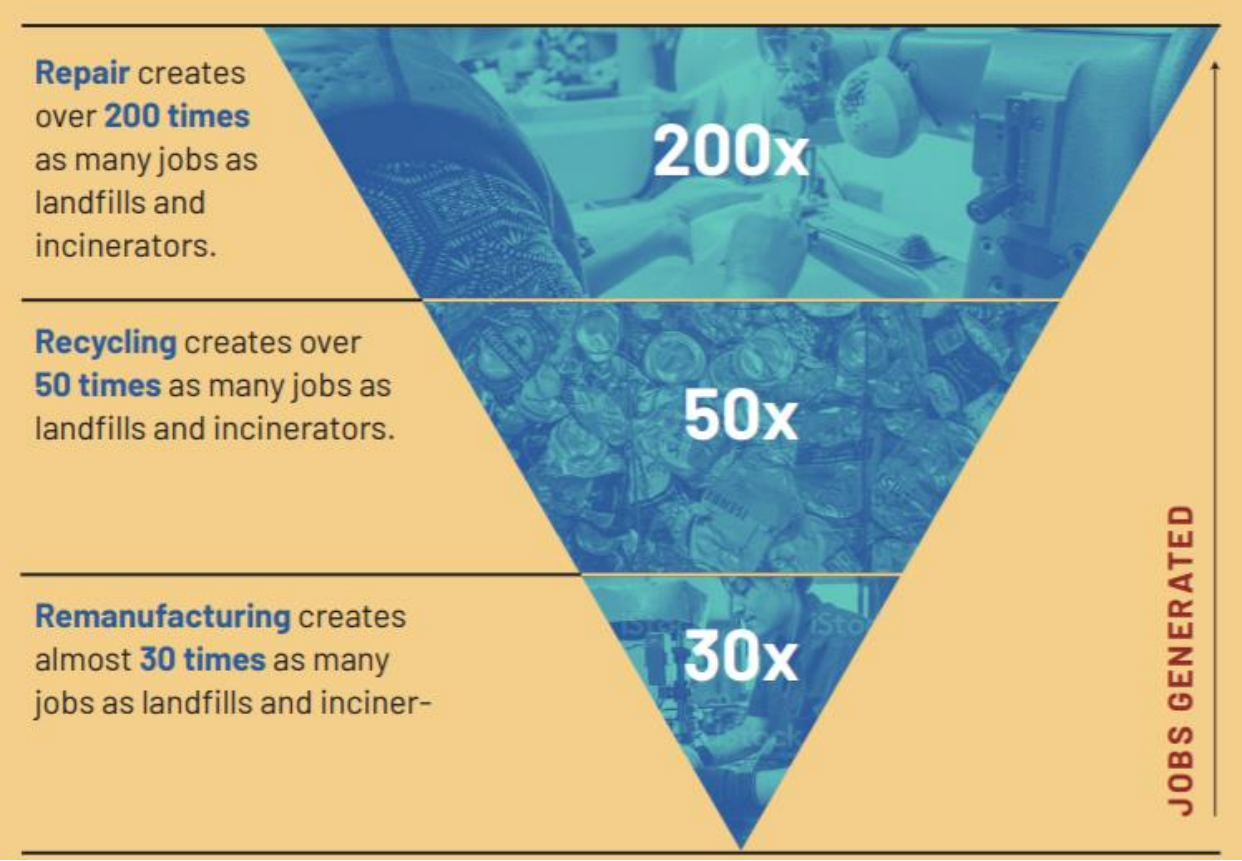

Figure 1-1. Illustration of circular economy opportunities associated with ZW2L implementation (Ribeiro-Broomhead & Tangri, 2021).

Landfills have several negative environmental impacts, of which the severity and likelihood will increase as more landfills are established. Some of the main negative environmental impacts associated with landfills include air pollution from waste burning and methane gas release, soil and water pollution caused by seepage from the landfill cells, leachate collection systems, uncontrolled spillages and discharges. This statement is supported by Danthurebandara *et al*, (2013:41) which also mentions an additional impact namely, the impact on land availability due to large space requirements by landfills.

In recognising the potential for global waste generation to increase as population growth increases, the UN developed a set of seventeen Sustainable Development Goals in 2015, with the 12th Goal specifically focusing on alternative waste management measures that will eliminate and minimise the need for disposal of waste to landfill (UN, 2015:27).

From a South African perspective, clear similarities can be drawn with these global waste management trends with about 93 million tons (77%) of the 121 million tons of waste generated per annum being disposed off at landfill (DEA, 2018:20&31). In an aim to address these concerns,

South Africa developed a National Waste Management Strategy, the latest of which is dated 2020 and built around three key strategic pillars namely:

- waste minimisation;
- effective and sustainable waste services; and
- compliance, enforcement and awareness.

As per DEFF (2020:33), the first pillar specifically covers waste minimisation by focusing on waste prevention and managing waste as a resource.

Anglo American Platinum (AAP) was used as the case study during this particular research as they are a globally recognised mining company and the first mining company in South Africa that has formally established a goal of achieving ZW2L. ZW2L is also embodied in their purpose statement "*Re-imagining mining to improve people's lives*" to create positive impacts on people's lives and the environment (AAPa, 2019:20). In 2013, the AAP board accepted the target, which can be argued as being ambitious at the time, to achieve ZW2L by the end of 2020.

The ZW2L approach in the case study includes hazardous and non-hazardous waste but is limited to the non-mineral waste and excludes the mineral waste portion for example tailings facilities, slag deposits and waste rock dumps. When this goal of ZW2L by end 2020 was adopted back in 2013, the total non-mineral waste sent to landfill at the end of that particular year was 22 000 tons (AAP, 2013:103). Fast forward to 2021, the total waste sent to landfill by the case study in 2020 was 1 760 tons with no waste sent to landfill in December 2020 (Anglo American, 2021). This is a 92% reduction in total waste sent to landfill and a trend-setting achievement in the mining industry. Along the case study's ZW2L journey there were numerous barriers encountered along the way, requiring innovative ways of overcoming these barriers, but it was also a journey during which various opportunities were realised.

Being a Minister of Environmental Affairs turned chairman of a platinum mining company, the need for change in the approach in waste management was identified early on by Valli Moosa. Although existing literature is available that covers the challenges and opportunities related to ZW2L, limited information is available from a mining company perspective and where literature is available it is mostly limited to the mineral waste portion of mining waste. The case study can therefore be regarded as a pioneer of the ZW2L approach for non-mineral waste in the South African mining industry, as the approach was not only limited a single operation, but was adopted by each individual mine, concentrator, smelter and refinery under the ownership of AAP. By studying and identifying the barriers encountered by the case study during this ZW2L journey, what actions they took to bridge these gaps and the opportunities realised, the information may

add value to other mining companies that want to follow the ZW2L approach. By covering the whole value chain from mining all the way through to refining, the potential value is not limited to platinum and other mining companies only, but also other industries with similar processes or that generate similar waste streams. By understanding the barriers, required actions and opportunities it will enable companies to plan their ZW2L journey accordingly, setting them up for success and be part of the solution to the current global waste management concerns.

1.3 Research aim and objectives

In light of the above problem statement the aim of the research is to determine: what barriers and opportunities may influence the implementation of the zero waste to landfill goal in the platinum mining industry?

In order to address the research aim, the following three research objectives are addressed:

- Identify barriers to zero waste to landfill implementation
- Identify opportunities from the zero waste to landfill implementation
- Identify measures required to bridge the gaps to overcome barriers

1.4 Scope of the research

The scope of the research is focused on AAP as a case study and includes all its operational facilities, namely: mines, concentrators, smelters and refineries. As a mining company, AAP has taken the lead and made significant strides in becoming the first South African mining company to achieve ZW2L across its entire operational footprint. The scope is limited to the non-mineral portion of waste and will exclude mineral waste for example tailings facilities, waste rock dumps and slag stockpiles.

The research will comprise of a review of existing international and national literature, AAP specific document analysis and individual interviews.

1.5 Structure and outline of the dissertation

The dissertation is made up of the following chapters.

- Chapter 1 which covers the introduction with specific sections for background, problem statement and rationale for the research study, research aim and objectives, scope of research, scope limitations and dissertation structure. Chapter 1 sets the scene for other chapters to follow.

- Chapter 2 covers the literature review that link the research aim with existing literature. The chapter focus on existing literature related to diversion of waste from landfill, international and national strategies to support the waste management hierarchy as well as challenges and opportunities related to the zero waste to landfill drive.
- Chapter 3 describes the research methodology used in terms of design, data collection through document analysis and interviews and analysis of collected data.
- Chapter 4 covers the analysis and interpretation of data collected in Chapter 3.
- Chapter 5 is the conclusion and recommendations of the research outcome and how it links back to the research aim and objectives.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter covers the literature review that links the research aim and objectives with existing literature, which will be achieved by first focusing on the meaning and alignment between ZW2L and the waste management hierarchy, followed by international and national frameworks developed to drive and support the ZW2L approach.

This will be followed by reviewing existing literature related to the barriers and opportunities experienced in the implementation of ZW2L as well as the actions that can be taken to bridge gaps and overcome the barriers.

The literature review was undertaken by accessing the on-line NWU Library at https://library.nwu.ac.za/ and utilising key words to search for relevant literature. The following key words were entered in the following combination: "*barriers AND opportunities AND zero AND waste AND to AND landfill AND platinum AND mining*" This resulted in a total of 1 501 documents, while limiting the search results to academic journals, narrowed down the search to 20 results. The search was further continued by utilizing the key words in different combinations for example: "*zero AND waste AND to AND landfill AND platinum AND mining"*, which yielded 87 sources when limited to peer reviewed academic journals. By reading the abstracts of some sources, the applicable links together with short summaries were saved in a separate excel spreadsheet for later access during the write-up of the literature review. References contained in some of these articles were then also utilised to access and review other potential literature review sources.

2.2 The ZW2L concept and alignment with the waste management hierarchy and integrated waste management.

When referring to a zero waste to landfill approach, it is exactly what the name implies in that no waste streams being generated are sent to landfill for disposal purposes. This ZW2L statement is supported by Gjetley & Pierre (2003:220), which describes a ZW2L facility as one that does not send any waste from their operations to a landfill. There is clear alignment in what ZW2L approaches set out to achieve and the waste management hierarchy, in that both approaches aim to identify and implement alternative management measures to divert waste away from landfill. The waste management hierarchy is described as the preference for action to reduce and manage waste (UNEP, 2018:13), while Alberts (2015:415) describes the waste management

hierarchy as the ranking of waste management alternatives based on their sustainability. It can be argued that the ZW2L approach and implementation of waste management hierarchy may both therefore achieve the diversion of waste from landfill, but as much as they are aligned in achieving diversion of waste from landfill, the ZW2L approach may not implement the most sustainable option available for waste streams in terms of the waste management hierarchy. The hierarchal approach in terms of preference is illustrated in Figure 2-1 as adopted from (DEFF, 2020:28). This waste management hierarchy, also referred to as the "*Ladder of Lansink*" (Lansink, 2018:872), was first established in 1979 and is also described as the framework for circularity.

Figure 2-1. The waste management hierarchy (DEFF, 2020:28).

This term of circularity as referred to by Lansink is better known as the circular economy and according to Franklin-Johnson *et al* (2016:590) the approaches of reduce, re-use and recycle are identified as principles (3R's) of the circular economy to deal with the fact that biological systems cannot be sustained with the current use of raw materials and subsequent generation of waste.

It can therefore be argued that the waste management hierarchy, circular economy and ZW2L are all based on the 3R's principles, ultimately contributing to the elimination of waste disposed to landfill and where elimination is not possible, to turn waste into a resource.

In order to identify potential ZW2L opportunities in terms of the waste management hierarchy, it is necessary to understand the individual waste streams, investigate and decide which options to implement based on the best approaches. This process is known as integrated waste management, which is described by Bosman *et al* (2018:1085), as a process that involves the consideration of waste classification, waste minimisation, treatment and disposal options and taking decisions while considering environmental and financial implications.

2.3 Frameworks established to support ZW2L through integrated waste management

Due to the prevalent linear economy approach that exists globally as well as in South Africa (DEA, 2018:20&31), it is important that a framework be established that encourages and supports integrated waste management and the transition to a circular economy approach. The United Nations established the Sustainable Development Goals (SDG) in 2015, with goal number twelve supporting waste management, through a focus on sustainable consumption and production in order to support the reduction, recycling and re-use of waste through an integrated waste management approach. From a South African perspective, section 2.3.2 will illustrate the broad framework established for integrated waste management and how it filters down from the National Development Plan (NDP) through to command and control-based approaches. Section 2.3.3 will briefly summarise waste legislative framework in Zimbabwe due to the fact that one of the case study's operations are situated in Zimbabwe, while section 2.3.4 covers literature on ZW2L from a mining perspective.

2.3.1 UN SDG's supporting the implementation of integrated waste management on international scale

In 2015, the Sustainable Development Goals were adopted by countries that are members of the United Nations. A total of seventeen goals were developed and the aim of the goals are described as a united approach and drive to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030 (UNDP, 2021). The global threat caused by an increase in the amount of waste generated, coupled with the high rate of disposal to landfill was acknowledged and SDG 12 was developed with a focus on sustainable consumption and production which ultimately support the reduction, recycling and re-use of waste through an integrated waste management approach. This statement is supported by specific targets that were established to support achievement of SDG 12, with target 12.5 specifically referring to substantial reduction of waste generation through prevention, reduction, recycling and reuse by 2023 (UNEP, 2015). It is interesting to note that this target makes specific reference to *waste generation* and not *waste disposal* and it can be argued that only the prevention and

reduction of waste will contribute to this target, whereas the re-use and recycling activities will reduce waste disposed to landfill. However, this is where the value of the Circular Economy approach as covered in section 2.2 becomes apparent, in that waste, once generated, is now regarded a resource and is no longer waste, which now fully supports the SDG target of reducing waste generation, whether through prevention, reduction, re-use or recycling. This statement is supported by (Minister Greecy, 2019) who states that "*There is no waste in a circular economy – when we have finished with something it becomes the raw material for something else".*

Although there are seventeen goals which are aligned and supportive of one another to ultimately achieve sustainable development, it can be argued that if we are to address the environmental and climate change problems we currently face, it must be ensured that SDG12 is linked to all relevant SDGs during implementation.

2.3.2 The South African framework approach to support integrated waste management

Being a member of the UN, South Africa form part of this global drive towards sustainable development though implementation of the SDG's. According to UNEP (2013:20), the member states, which include the South African government can make a critical contribution to integrated waste management by:

- including waste management as part of the national priority focus areas;
- providing resources and support to local government to enable implementation of integrated waste management;
- developing clear and aligned policies supporting integrated waste management;
- providing an environment at local government to enable the building of skills, knowledge and capacity for effective implementation of waste management programs; and
- promoting the development of schemes and markets to enable moving waste up the waste management hierarchy through recycling and re-use.

Other than this international pressure on government to support integrated waste management, local government in South Africa is legally required to support national and provincial authorities with integrated waste management, ensuring that the country is kept clean (Alberts, 2015:409). The foundations of this mandate being Section 24 of the *Constitution of South Africa* (1996) and the *National Environmental Management: Waste Act* 59 of 2008 (NEM: WA). Section 24 of the *Constitution of South Africa* (1996) states that people have a right to an environment that is not harmful to their health and well-being, while the objective of NEM: WA, as set out in Section 2 is to provide for waste management measures that will protect health, well-being and the

environment. This objective is supported in particular through Section 16 of the NEM: WA which compels society in general to take reasonable measures in preventing waste from being generated and disposed, by considering avoidance, re-use and recycling opportunities. The NEM: WA, however, was not only promulgated in order to meet the needs of the Constitution, but is a result of the overarching environmental legislation in South Africa, namely the *National Environmental Management Act* 107 of 1998 (NEMA) and meeting its related principles as set out in Section 2 of NEMA. One of the NEMA Section 2 principles, which may be argued is synonymous with waste management is the “cradle-to-grave principle”. In line with this principle, the generator of waste remains liable for the waste generated during storage, transport and disposal. The implication as described by Oosthuizen *et al*. (2018-142), is that the waste generator’s responsibility is not limited to the duration for which the waste is under the generator’s control, but continues thereafter. This requires a life-cycle model of approach, through which waste generation, disposal and associated liabilities can be avoided and reduced through detailed planning and implementing the waste management hierarchy.

In order to meet the above international and national obligations, South Africa developed the White Paper on Integrated Pollution and Waste Management of 2000. It was the first policy document in South Africa that outlined the new way of thinking about waste and in particular environmental degradation, which changed from prevention of waste and pollution, rather than treatment and remediation thereof (DEAT, 2000:5). The White Paper identified the absence of integrated waste management options and outlined the approach in chapter 4 of the Paper with a specific focus on waste management in section 4.2.4 of the Paper. This was followed by establishing a set of goals in chapter 5 of the Paper to achieve what was set out in this policy document. The approach have some similarities with the latest framework developed for South Africa in 2010 described in the sections to follow. This framework consists of the National Development Plan (NDP), Medium-Term Strategic Framework (MTSF), Presidential Outcome 10 and the National Waste Management Strategy (NWMS).

2.3.2.1 The National Development Plan (NDP) and integrated waste management

In May 2010, a commission was appointed by the President of South Africa with the objective to identify shortcomings and gaps on dealing with poverty and inequality since 1994, when South Africa became a democratic republic. The commission produced a report on their findings and the NDP was developed to address the findings of the report (National Planning Commission, 2012:25). The plan sets out to address these high-level findings by 2030, which also aligns with the SDG targeted timeframe.

How does the NDP provide a framework for IWM? Chapter 5 of the NDP focus on "*Consumer awareness initiatives and sufficient recycling infrastructure should result in South Africa becoming a zero-waste society*" (National Planning Commission, 2012:197), which links the NDP directly with Sections 16 of the NEM: WA, which supports the consideration and implementation of the waste management hierarchy as covered in section 2.2.

It must however be kept in mind that the NDP takes on the role of policy in South Africa with high level and long-term actions on what must be achieved. In order to track progress and ensure these long-term actions can be met, more precise medium-term actions must be developed to support implementation of the NDP.

2.3.2.2 The Medium-Term Strategic Framework (MTSF) and integrated waste management

The MTSF is a medium-term plan that supports the implementation of the long-term NDP (Republic of South Africa, 2014:4). These medium-term focus areas in the MTSF are termed "*Outcomes*" and a total of twelve Outcomes have been established.

The link to Chapter 5 of the NDP becomes clear in Outcome 10 of the MTSF, which relates to the protection and realization of positive impacts on the environment. The link between MTSF and IWM is also further supported by the specific reference to improving waste management through investment in recycling infrastructure (Republic of South Africa, 2014:30). Once again, this approach by the MTSF aligns with Sections 16 of the NEM: WA to prevent waste generation through the re-use and recycling of products through the waste management hierarchy.

2.3.2.3 Presidential Outcome 10 and integrated waste management

Detailed targets, actions and agreements were then developed for each of the MTSF Outcomes, known as Key Performance Indicators (KPI's) and this KPI document linked to MTSF Outcome 10 is then referred to as Presidential Outcome 10 (DEA, 2010:1). In the case of Presidential Outcome 10, four specific Outputs were created, with specific Sub-outputs identified for each output, with detailed action plans and responsibilities.

Although waste is a specific focus point under Output 3, it can be argued that the Sub-output focus of "*less and better managed waste*" will also contribute to all the other Outputs, for example:

- Enhanced quality and quantity of water – *less and better managed waste* will result in less littering and potential run-off into surface water, less disposal and potential for seepage into groundwater, thereby supporting the enhancement of water quality.
- Reduced greenhouse gas emissions, climate change & improved air/atmospheric quality – *less and better managed waste* will result in less methane gas generation from landfills, less illegal burning of waste and as such reduce air quality related impacts.
- Protected biodiversity – *less and better managed waste* will protect animals, plants and the resources required by them for survival against the negative impacts caused by waste products in the environment.

The link between Presidential Outcome 10 and IWM and a drive towards ZW2L becomes clear when considering the key waste management activities covered in the documented plans, namely:

- improved municipal waste collection;
- licensing of landfills;
- diversion of waste from landfill (Supports ZW2L);
- review of the waste tariff structure to support (incentivise) waste minimisation (Supports ZW2L);
- inclusion of re-use and recycling targets in industry waste management plans (Supports ZW2L);
- characterisation of waste (Once waste characteristics is known, ZW2L opportunities can be investigated); and
- implementation of waste information system.

2.3.2.4 The National Waste Management Strategy (NWMS) – Pulling it all together

The previous NWMS, dated 2011, not only contributed to Output 2 and Output 3 of Presidential Outcome 10, but also to Presidential Outcomes 4, 8 and 9 (DEA, 2011:17). With the latest 2020 NWMS, the eight goals from the 2011 NWMS are consolidated into three outcomes while the actions linked to achieve the outcomes, replaced the 2011 NWMS targets (DEFF, 2020:39), which provides a clear path from the NDP through to the NWMS. The 2020 NWMS through support of three pillars, namely Waste Minimisation; Effective and Sustainable Waste Services; Compliance, Enforcement and Awareness, will see a future South Africa with zero waste in landfills (DEFF, 2020:7).

The 2020 NWMS pulls it all together as it is aligned to the UN Sustainable Development Goals (SDGs) and responds to South Africa's National Development Plan (NDP) (DEFF, 2020:7) and

supports the implementation of the NEM: WA through a circular economy approach. The 2020 NWMS also supports the argument by WasteAid as referenced in section 2.3.1 that integrated waste management is key to not only achieve SDG 12, but contributes to the achievement of all the other SDG's (DEFF, 2020:16). The importance of IWM to achieve ZW2L can therefore not be underestimated.

2.3.3 The Zimbabwean approach to support integrated waste management

Since one of the case study's operations are situated in Zimbabwe, the integrated waste management framework for Zimbabwe must also be considered as part of the literature review.

When Zimbabwe reviewed its Constitution in 2013, it followed the South African approach by including environmental rights into its Constitution. According to Chirisa & Muzenda (2013:6), the Constitution of Zimbabwe, which was gazetted on 22 May 2013, makes provision for environmental rights in section 73 and is a result of external pressures, for example the approaches followed by the UN and South Africa.

Whereas the NEMA and NEM: WA from a South African perspective was a direct result to support and achieve section 24 of the South African Constitution, the 2013 Constitution of Zimbabwe and its section 73 requirements were already covered through the Environmental Management Act (EMA) 13 of 2002. To support the EMA in terms of waste management the Chapter 20:27 Environment Management Act (Hazardous Waste Management) Regulations and Chapter 20:27 Environment Management Act (Effluents and Solid Waste Disposal) Regulations were published in 2007.

Part 4 in the Chapter 20:27 Environment Management Act (Effluents and Solid Waste Disposal) Regulations and section 13 in the Chapter Environmental Management Act (Hazardous waste management) Regulations make provision for waste management plans to be developed to reduce, re-use and recycle waste to minimise disposal. Zimbabwe also developed the integrated solid waste management plan in July 2014, setting out ten goals (EMA, 2014:5), of which each one will support moving up the waste management hierarchy.

2.3.4 ZW2L approach from a mining perspective

During the literature review it was challenging to find existing literature that covers ZW2L for non-mineral waste from an overall mining perspective, never mind platinum specific mining. Literature was found to be limited and focused on mineral waste associated with mining and not the non-mineral waste portion.

This observation and challenge are also acknowledged by Singh *et al*. (2020:2), which states that although there is literature available that covers barriers to adoption of circular business models, the availability of literature is limited from a mining industry perspective. Applicable and key findings from the study conducted by Singh *et al*. are referenced in the literature review in section 2.4.4.

2.4 Barriers in implementing ZW2L

Talking and striving to achieve ZW2L is one thing, but achieving it requires a paradigm shift from all stakeholders involved, to move away from a culture of linear economy to a circular economy approach. ZW2L initiatives are often complex projects requiring unprecedented transformation and often fail due to a lack of planning and leadership, resistance from role players and a focus on re-use and recycling instead of reduction (Krausz, 2012:iv). In this section the focus will be on the main barriers that can challenge or prevent the successful implementation of ZW2L as identified through the literature review. Govindan & Hasanagic, (2018:300), classified barriers in implementing ZW2L into eight clusters, namely:

- governmental issues – lack of standards, policies and legislation to support ZW2L;
- economic issues related to financial barriers in implementing ZW2L;
- technological issues – lack of technology to implement off-takes related to ZW2L;
- knowledge and skill issues – lack of awareness and skills to support ZW2L;
- management issues – lack of top management support in implementation of ZW2L;
- circular economy framework issues;
- culture and social issues – lack of interest towards re-use of products; and
- market issues - externalities that prevent use of refurbished products.

It can be argued that these barriers can be further simplified and grouped into four barriers as per Table 2-1 and an additional barrier be added as *environmental impact*. Kerdlap *et al*. (2019:16) identified that some measures taken to implement ZW2L may result in toxic fumes that pollute the environment, which can ultimately cause bigger environmental impacts than landfilling.

Table 2-1. Five prominent ZW2L barriers.

No	Consolidated ZW2L barrier	Individual barriers (Govindan & Hasanagic, 2018:300)
1	Legislative barriers	Government policies and legislation issues
2	Financial barriers	Economic and market issues
3	Infrastructure and Technological barriers	Technological issues

4	Human factor barriers	Knowledge, skills, cultural and management
5	Environmental impact barriers	Environmental impacts (Kerdlap *et al*., 2019:16)

The following sections will focus on existing literature to expand on each of these five ZW2L barriers.

2.4.1 Legislative barriers

Govindan & Hasanagic, (2018:305) makes a specific reference to China in that the lack of legislation to enforce recording of waste generated and disposed results in local government agencies not being able to pinpoint the areas of concern and act accordingly. In South Africa, this lack of information is countered by having specific regulations in place in the form of Government Notice Regulation 625 and the electronic South African Waste Information System (SAWIS) platform provided for waste related reporting purposes and allowing government to establish state of waste reports and the NWMS to deal with concerns identified.

It is not just the lack of legislation that can be a barrier in the drive towards ZW2L, but the lack of enforcement and ironically the legislation itself, that is supposed to support IWM and protect the environment, that is counterproductive. UNEP (2018:55) states that waste management in South Africa provides a framework for successful IWM, but that enforcement is a serious gap, while De Jesus & Mendonca (2018:82) states that in as much as legislation plays a role in driving change, it can also limit the implementation of ZW2L. A typical example in the South African context, was the inclusion of waste related activities normally associated with supporting a ZW2L approach, namely into the list of waste management activities which required the need for a waste license. With the costs and time constraints involved with license applications and subsequent requirement to meet onerous license conditions, there was no motivation to implement these measures towards ZW2L, as disposal to landfill was an easy alternative. The example used above, has since been rectified through the promulgation of GN R1093 in 2017, providing for the Norms and Standards that need to be complied with when sorting, shredding, grinding, crushing, screening or baling of general waste, replacing the need for a waste license.

2.4.2 Financial barriers

According to Grafström (2021:6) the markets to support ZW2L are not effective as the implementation of ZW2L alternatives in some instances requires excessive capital input and the low value associated with most recycled products. It is further stated that the reason for low

value is caused by perceptions that the products might be of inferior quality for re-use purposes in conjunction with perceived low cost with acquiring and utilising raw materials instead of recycled materials.

Findings by Rizos (2016:10) indicate that 50% of the sampled companies indicated that lack of capital and proving business case is a financial barrier to move from a linear to a circular economy and support ZW2L initiatives. Although it is noted that the reference to capital also included time and human resources, it makes sense to include this under financial barriers, as R&D related costs, instead of the section under "*human factor barriers*".

It is acknowledged that recycling must be incentivised in Zimbabwe (ISWA, 2021) and the lack of current financial incentives are a barrier in promoting re-use and recycling. Once the solution for this barrier is implemented, there are opportunities to be realised as covered in sections 2.5.1 and 2.5.2.

2.4.3 Infrastructure and technological barriers

For recycling and re-use requirements to be met, infrastructure to enable effective waste separation, sorting, storage and collection is required. This statement is supported by Kerdlap *et al*. (2019:15) by indicating that dedicated material recovery facilities in Singapore, enables a recycling rate of 60% to be maintained. Colour coded bins are supplied to households to encourage at-source sorting to prevent mixing of recyclables and non-recyclables which ultimately lead to contamination and preventing further recycling.

In contrast to the above example of Singapore, South Africa face infrastructure challenges such as lack of transport, equipment and waste sorting and storage premises (Godfrey & Oelofse, 2017:6). A key input into the Circular Economy aspects of the 2020 National Waste Management Strategy (NWMS) was derived from the Chemicals and Waste Phakisa that was held, resulting in an acknowledgement by DEFF (2020:52) and subsequent response with a focus on the following technologies:

- Biological Treatment (Anaerobic Digestion / Fluidised Bed Reactors);
- Material Recovery Facilities and palletisation;
- Composting and re-use of household biomass;
- Waste-to-Energy plants;
- Pyrolysis; and
- the use of ash, sludge and animal matter as a soil ameliorant and input to high agricultural production land.

2.4.4 Human factor barriers

Research conducted by Govindan & Hasanagic, (2018:301) indicated that the barrier that appeared most often was consumer perception towards recycled products, followed by lack of awareness of CE towards ZW2L. Awareness place a crucial role in that even if you have the technology and infrastructure available for ZW2L, if awareness is lacking to support for example at source sorting, ZW2L cannot be successful. Another human factor and arguably one of the most important is the lack of decision making at the top management level (Singh *et al*., 2020:4). If buy-in and commitment cannot be obtained from top management, a company cannot be successful in the implementation of ZW2L. Various of the other barriers for example financial and infrastructure can also be overcome by having the support from top management in driving ZW2L.

2.4.5 Environmental barriers

As already alluded to in the discussion on the waste management hierarchy, some ZW2L alternatives are more favourable and sustainable than others, while in some cases the available ZW2L offtakes can cause more environmental harm than the actual disposal to landfill. This statement is supported by Kerdlap *et al*. (2019:16) by using the example of treating electronic waste through pyrometallurgical methods will result in toxic fumes, leading to air pollution. Actions to potentially overcome this barrier is covered in section 2.6.5.

2.5 Opportunities from the ZW2L implementation

From the literature review, three main areas have been identified in which opportunities exist when companies implement ZW2L and it is very interesting to note that the main opportunities identified, are perfectly aligned with the pillars of the sustainability framework as per Figure 2-2, adopted from Rizos *et al*. (2016:7).

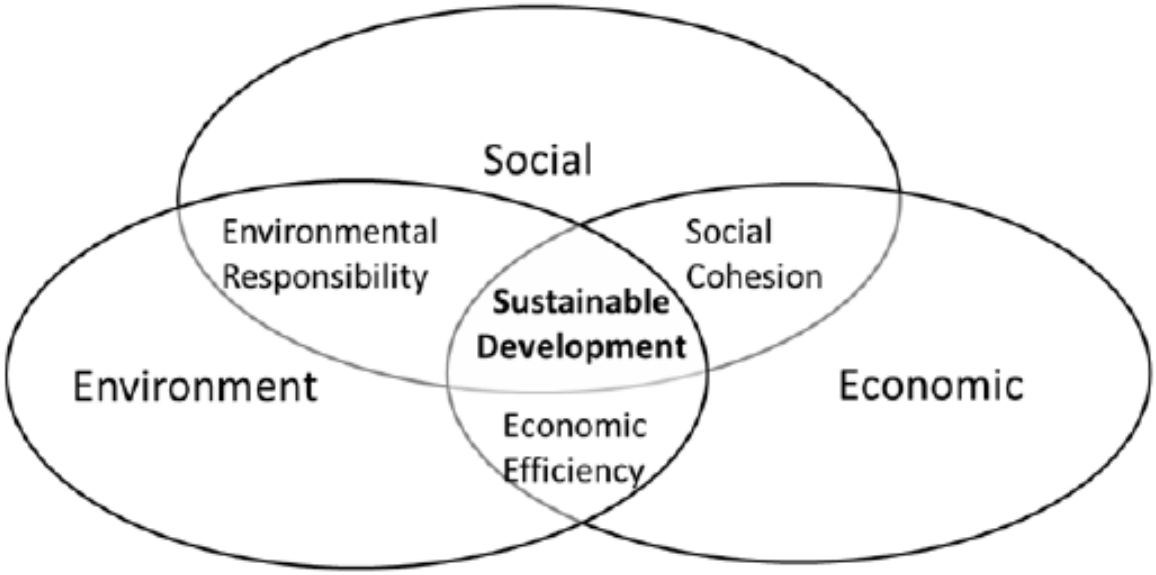

Figure 2-2. Illustration of how pillars are interlinked to support sustainable development (Rizos *et al*., 2016:7).

2.5.1 Financial/economic opportunities

The focus on Corporate Social Responsibility (CSR) by mining companies have increased to the extend where it is being incorporated into their integrated risk management strategies as it provides them with a competitive advantage related to acquiring loans and capital from investors (Frederiksen, 2018:503). Fernando (2021) defines CSR as "*a self-regulating business model that helps a company be socially accountable - to itself, its stakeholders, and the public*" and companies can use ZW2L with its link to the sustainability pillars, as a contributing factor to CSR.

The achievement of ZW2L will render landfills obsolete and once the need for development of new landfills are no longer required, the costs associated with landfill development can rather be used for supporting ZW2L initiatives, while the revenue generated from recycling will contribute to cashflow (Matete and Trois, 2008:1490).

ZW2L approaches also provide companies with the opportunity to off-set carbon tax, which includes methane gas, by installing biodigesters to convert organic waste into a sustainable energy source. This statement is supported by Carvalho *et al.* (2020:100), which states that under developed and developing countries make use of biodigesters to convert organic waste to biogas to eliminate dumps of organic waste.

By incentivising the re-use and recycling of waste, value will be attributed to waste and disposal to landfill will be minimised. This is an opportunity at both the source but also for the informal sector which is an opportunity that can be utilised to establish formal job opportunities.

2.5.2 Community benefit opportunities

According to Nuur *et al*. (2018:108) the establishment of mines result in the establishment of businesses to support mining needs and that the opportunity presents itself to also identify entrepreneurs in surrounding communities to uplift them and address imbalances. By providing communities the opportunity to get involved in recycling and sorting facilities these opportunities can be realised through ZW2L.

This also proves how ZW2L can contribute to the Green Economy, which is defined as a system of economic activities related to the production, distribution and consumption of goods and services that result in improved human well-being over the long term, while not exposing future generations to significant environmental risks or ecological scarcities (DEA, 2020).

Creating awareness and changing the human mindset around the value in waste, may support the reduction, re-use and recycling of waste and at the same time provide local communities with job opportunities (ISWA, 2021).

2.5.3 Environmental opportunities

ZW2L initiatives provide opportunities to increase the lifespan of existing landfills, saving air-space (Matete and Trois, 2008:1490) and less new landfills will result in a reduction in potential pollution of water, air and soil. This is particularly important when it comes to non-biodegradable waste streams, which often tend to accumulate in biological cycles and form toxins which remain in earth for up to centuries (Velvizhi *et al*., 2020:9).

2.6 Bridging the gaps to address ZW2L barriers

In considering what measures can be taken in order to bridge the gaps, the focus will be on the barriers identified and their associated potential solutions.

2.6.1 Bridging legislative barriers

An example of addressing the barrier introduced by legislation in South Africa related to the sorting, shredding, grinding, crushing, screening or baling of general waste, the South African government in realizing this barrier introduced amendments through GNR 1094 (2017), which

meant that these waste activities no longer required a waste license and should only comply with National Norms and Standards as per GNR 1093 (2017).

A strong legislative framework as covered and illustrated under section 2.3.2 of this document is required to bridge legislative barriers. Although the framework as described in section 2.3.2 has indeed been developed in the South African context, definite further legislative changes as well as compliance and enforcement is required to finally overcome legislative barriers in the ZW2L approach.

2.6.2 Bridging financial barriers

Rizos (2016:14) indicates that an important enabler to overcome financial barriers towards ZW2L is company leadership that considers the circular economy as part of an integral part of their business model. This will ensure that the necessary capital is provided for infrastructure requirements, training and awareness as well as research and benchmarking against other companies. This clearly illustrates that company leadership is not only important to address the financial barriers, but also barriers in terms of infrastructure and human barriers by setting an example to employees and sending out the message about ZW2L.

2.6.3 Bridging infrastructure and technological barriers

According to Gjetley and Pierre (2003:223), valuable knowledge about available technologies can be obtained through benchmarking and visiting companies with experience in the ZW2L approach.

From a Zimbabwean perspective, it is acknowledged that recycling needs to be a part of a holistic strategy to be successful (ISWA, 2021). The availability of infrastructure and technology plays an important role in this regard.

As mentioned in section 2.6.2, company leadership is a key enabler to bridge the gap related to infrastructure and technological barriers in achieving ZW2L.

2.6.4 Bridging human factor barriers

Gjetley and Pierre (2003:222) indicates various measures that may be utilised to increase awareness and that active participation in activities allow employees to get involved and take ownership. Ongoing training and awareness methods can be utilised for example dedicated ZW2L newsletters and ZW2L wall art. Again, the leadership role mentioned in 2.6.2 is a key enabler in addressing and changing behaviour.

2.6.5 Bridging environmental barriers

In order to bridge the gap identified in section 2.4.3, life cycle analysis must be undertaken on waste to resource uses to ensure industrial symbiosis and implement best ZW2L alternatives to prevent merely shifting environmental impact potential from one sphere of the environment to another (Kerdlap *et al*. 2019:16).

This is a great example of the important role the waste management hierarchy can play, in that reducing and preventing waste from being generated, the need for treatment and potential shifting of environmental impacts can be prevented.

CHAPTER 3 METHODOLOGY

3.1 Introduction

This chapter describes the research methodology that was used, together with the research design, data collection and data analyses methods used to address the research question.

The research methodology was based on a case study approach with mixed research methods which included document analysis and interviews. The case study approach, according to Crowe *et al.* (2011:8), allows interventions to be studied in detail in a real-life context, which meant that the ZW2L case study could successfully be used to identify the barriers, opportunities and how to bridge gaps, based on actual experiences of the parties involved in the implementation. There are four tests and associated tactics that can be used to determine the relevance of the case study approach for a particular research topic (Yin:2018). Through Table 3-1, the relationship between the tests and this particular research topic was confirmed and illustrated.

Table 3-1. Yin's four tests and the link with this research to support the case study approach.

Tests	Case study tactic	Relationship with this particular research
Construct validity	Use multiple sources of evidence	Various documents as listed under 3.3.1 as well as semi-structured interviews, described in 3.3.2, were used as sources of evidence.
Internal validity	Do pattern matching Do explanation building	This was achieved through data analysis as described in 3.4.
External validity	Use theory in single-case study Use replication logic in multiple-case studies	As described in 3.2, the case study included all underground and opencast mines, concentrators, smelters and refineries. The case study's barriers and opportunities related to its ZW2L approach covered a broad spectrum of individual waste streams. The applicability of the research outcome will therefore not be limited to AAP or other mining companies only, but will also be representative of metallurgical related activities.

Reliability	Maintain a chain of evidence	Records of evidence in the form of reports and interviews are available.

3.2 Research design

A critical step in the reasearch design is to set the boundaries of the case to be studied (Yin:2018). The specific case study of a platinum mining company was chosen, as the company in question is leading the current ZW2L implementation for mining companies in South Africa. The boundaries of the case study is thus limited to AAP as a company but based on the fact that the research included all underground and opencast mines, concentrators, smelters and refineries, the case study's barriers and opportunities related to its ZW2L approach covered a broad spectrum of individual waste streams. The applicability of the research outcome will therefore not be limited to AAP only, but also other mining companies.

AAP's operations are grouped as the western limb and far eastern limb operations in South Africa and one mining, concentrating and smelting complex located in Zimbabwe. The western limb operations as per Figure 3-1 comprise of:

- Operation 1 which comprises of mine and concentrators complex;
- Operation 2 which comprises of mine and concentrators complex;
- Operation 3 which is a smelter;
- Operation 4 which comprises of a smelter and converter plant;
- Operation 5 which is a base metals refinery; and
- Operation 6 which is a precious metals refinery

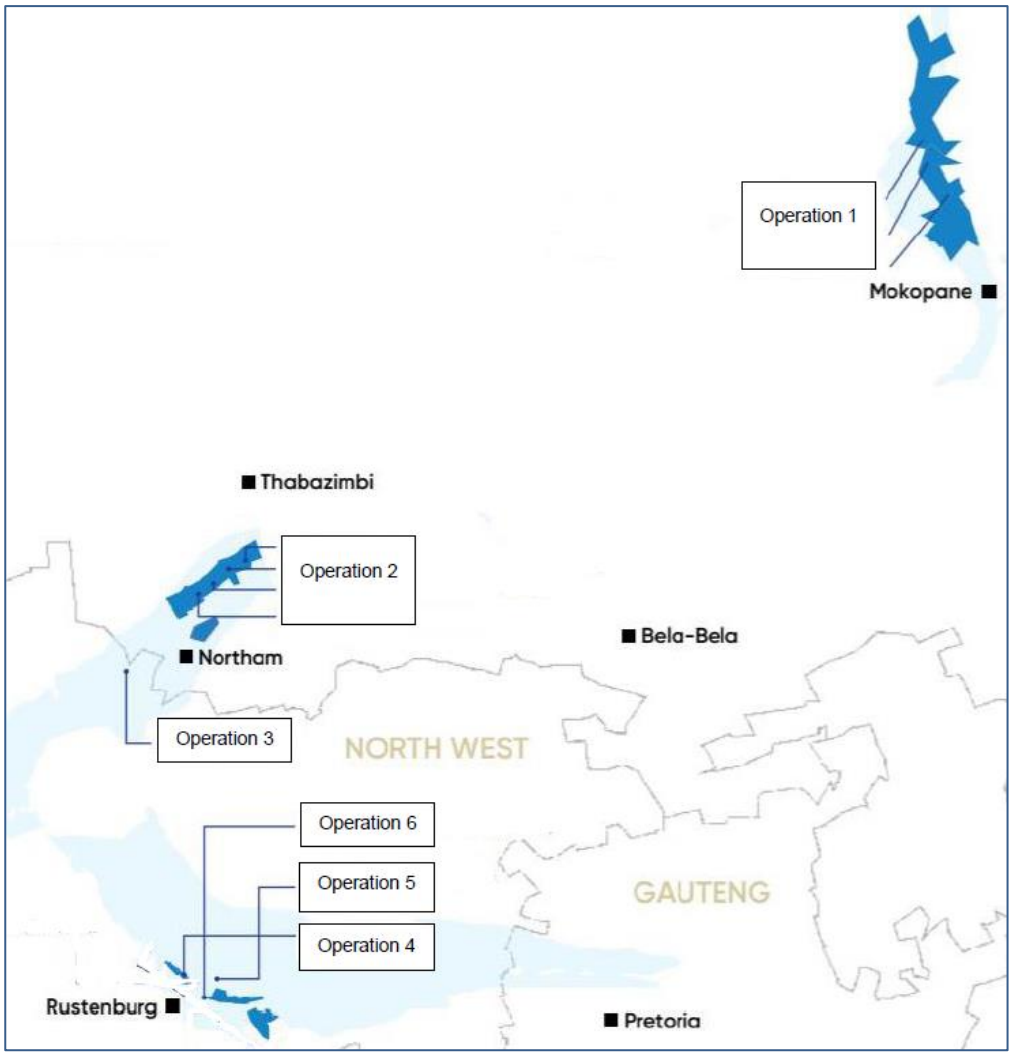

Figure 3-1. Location of Western Limb operations (AAP, 2020:2).

The far eastern limb and Zimbabwe operations as per Figure 3-2 comprise of:

- Operation 7 which is a smelter;
- Operation 8 which is a mine;
- Operation 9 which comprises of mine and concentrators complex; and
- Operation 10 which comprises of mines, concentrators and smelter.

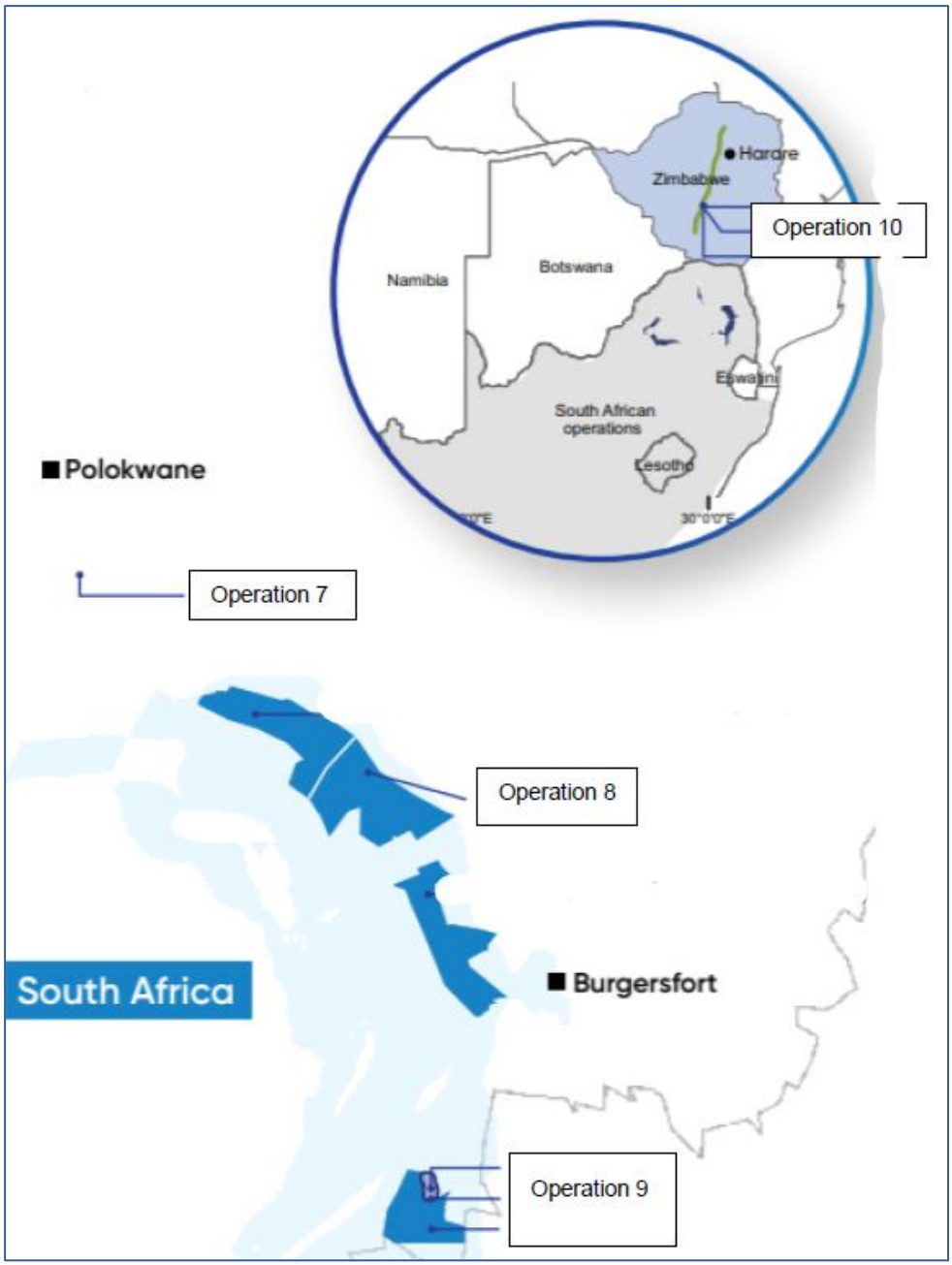

Figure 3-2. Location of Eastern Limb operations and Unki (AAP, 2020:3).

3.3 Data collection

Data collection was undertaken through document analysis and interview methods. The document analysis and interview methods enabled information to be gathered based on actual experience from the teams and individuals involved in the case study implementation of ZW2L. Through this data collection and subsequent data analysis, the barriers and opportunities that may influence the implementation of the zero waste to landfill in the platinum mining industry were identified and addressed the research question. It is acknowledged that both these research methods have their strengths and weaknesses, which made it important to plan on how to use

the strengths and overcome the weaknesses during the research. Some of the strengths and weaknesses, as well as reasons for choosing these particular methods are also discussed in the relevant sections that follow.

3.3.1 Description of document analysis

Document analysis is a systematic procedure for reviewing or evaluating documents both printed and electronic (computer-based and Internet-transmitted) material (Bowen, 2009:27). According to Bowen (2009:31), some of the strenghts of using document analysis for data collection is that document can be readily available and an efficient and cost-effective method of research, but warns that document analysis is not always advantageous as it may contain insufficient detail and some documents may be irretrievable.

These strenghts and weaknesses were considered during the research as illustrated in Table 3-2.

Table 3-2. Considering the strengths and weaknesses of document analysis in the research.

Strenghts	Maximising strenghts during this research
Availability	Being an AAP employee, access to various documents were readily available. However, most of the information is also contained in documents that are available to the public, e.g. ESG reports.
Cost-effective	Due to the documents being readily available, no financial costs were required to be incurred in order to have access to these documents and obtain the information contained therein.
Weaknesses	**Overcoming weakness during this research**
Insufficient detail	The document analysis approach was complemented with the interviews that followed. Where detail was lacking or not clear from the document analysis outcome, these were clarified during the individual interviews.
Irretrievable	The documents that were reviewed forms part of the overall record control. The operations are all ISO 14001:2015 certified and record control is a key requirement in terms of the standard. The relevant record matrix can be utilised to retrieve these records. The information that are available through the AAP website can be accessed by the public, including the historical ESG reports for example.

The following list of documents were included in the analysis:

- Overarching AAP ZW2L strategy document (one report);
- Operational specific ZW2L strategy documents (ten reports);
- AAP annual ESG reports (2013 – 2020), as the ZW2L initiative commenced in 2013; and
- Enablon data – Enablon is the software program used by AAP for capturing of monthly data, including waste related data. The data from individual operations feed into the AAP ESG report after undergoing an assurance audit for data accuracy and retrievability;

The information from these documents were used to identify waste streams and quantities per operation, spikes caused by sudden increases and decreases in waste sent to landfill from the case study point of view, long term trends and comparing ZW2L performance between individual operations. These observations made during the document analysis are discussed in chapter 4 and were also focused on during the interviews to understand the reasons behind these observations. By combining the observations made from the document analysis with the information obtained during interviews, the main ZW2L barriers, opportunities as well as actions taken to overcome barriers were identified as described in Chapter 4.

3.3.2 Description of interviews

The information obtained from the document analysis was used to develop the interview questionnaires and by interviewing the key role players involved in the ZW2L, assisted in identifying the barriers and opportunities that contributed to the observations made from the document analysis. As was the case with the document analysis, it is acknowledged that interviews as a data gathering method also have strengths and weaknesses associated with it. While (Fox 2009:4) warns that a poorly designed interview may include leading questions or questions that are not understood by the participants, the use of semi-structured interviews can also provide the opportunity for the interviewer and interviewee to discuss some topics in more detail. To counter this warning, the interviews were limited to participants that were involved in the ZW2L drive, ensuring background knowledge of the overall ZW2L implementation and the semi-structured interviews ensured the added advantage of providing the opportunity for detailed discussions of trends and spikes identified during the document analsyis undertaken. By discussing the trends and spikes (increases and decreases) in the ZW2L performance, certain barriers and opportunities related to these were identified, together with the actions taken to address some of these barriers.

In order to limit physical face-to-face engagement considering the current Covid-19 pandemic and associated risks, the interviews were undertaken through Microsoft Teams. Microsoft Teams is a

software system that can be utilised to meet with individuals or teams via computers, laptops or mobile devices connected with the internet. Microsoft Teams allows participants to observe and listen to one another through video and audio systems on the devices being used, while also providing the option for sessions to be recorded for playback. Utilising Microsoft Teams not only provided a safe platform for one-on-one interaction, but proved to be a cost-effective method, was readily accessible and eliminated the need to spend time travelling to individual operations. These observations are supported by Archibald *et al.* (2019:4), which found that these tools are cost effective, time effective, user-friendly and supports maintaining rapport between the interviewer and interviewee, especially when compared to "nonvisual" communication mediums such as telephone or e-mail. Although Archibald's findings are based on Zoom as the software program, Zoom and Microsoft Teams are based on similar platforms.

A total of fifteen individuals were interviewed, which included the following:

- Appointed waste champions for mines, concentrators, smelters and refineries (ten);
- Lead Environment: Platinum (one);
- Environmental manager of AAP's eastern limb operations (one);
- Group Principle: Product Stewardship (one);
- ZW2L partner lead (one);
- Supply Chain resource dedicated to ZW2L drive (one); and

The interview questionnaires were distributed to the interviewees via a cloud-based software programme, named Smartsheet. This was followed by one-on-one Microsoft Teams session with each individual to discuss the questionnaire, clarify any questions where required and ask follow-up questions as part of the semi-structured approach. The interview questionnaire template used is contained in Annexure A.

3.4 Data analysis

The importance of data analysis is highlighted by McNabb (2010:287), which states that data gathered through various methods are of little meaning if the data is not processed, analysed and interpreted by the researcher.

During the document analysis, certain key words were focused on and clustered into the five main ZW2L factors as identified during the literature review as per Table 3-3.

Table 3-3. Examples of key words and their consolidation into five main ZW2L factors.

No	Consolidated ZW2L factors	Examples of key words focused on during the document analysis
1	Legislative	Policies, legislation, treaties, conventions, acts, regulations, legal, licence, permit etc.
2	Financial	Economy, market, finance, budget, cost, income, savings, business case etc.
3	Infrastructure and Technology	Waste sorting area, salvage yard, waste storage facility, waste treatment, waste re-use, waste recycling, waste to resource, alternative fuels etc.
4	Human factors	Awareness, training, competence, compliance, support, buy-in, jobs, communities, management, employees, culture etc.
5	Environmental	Incineration, landfill, diversion, emissions, effluent, pollution, land/soil, rehabilitation, remediation etc.

Following the consolidation of information obtained during document analysis against the five main ZW2L factors, the information was aligned with the research objective by further clustering it into:

- Barriers identified during the implementation of ZW2L by the case study;
- Opportunities identified during the implementation of ZW2L by the case study;
- Actions taken by the case study to address barriers.

On occasions where documentation did not provide clear explanations for certain trends and spikes in ZW2L related graphs and data identified during the document analysis, these were noted for follow-up and discussion during the semi-structured interviews. During the semi-structured interviews, the individuals were asked to focus on each of the five consolidated ZW2L factors and indicate if they experienced each factor as a barrier, opportunity, both a barrier and opportunity or none. This was followed by requesting them to elaborate on their choices by providing reasons and examples from their own experience during the case study's ZW2L drive.

The interviewees were then requested to indicate what actions were implemented to overcome each of the barriers that they identified during the semi-structured interview.

Key words were noted and written down during the individual semi-structured interviews and recordings were made utilising the Microsoft Teams recording function with consent provided by the interviewees. Following the interviews, the notes and recordings were analysed to confirm once again in which of the five consolidated ZW2L factors the information obtained fits and confirm barriers, opportunities and actions identified.

The results obtained from the analysis of the data gathered during the document analysis and interviews are discussed in Chapter 4, together with a summary on how these results compare with the barriers, opportunities and actions related to the ZW2L factors identified during the literature review in Chapter 2.

3.5 Ethical considerations

Based on the review by the North West University, Faculty of Natural and Agricultural Sciences Ethics Committee (FNASREC), the Committee cleared this study as having no ethical risk. FNASREC granted permission to initiate this study under ethics number NWU-00454-21-A9.

3.6 Methodological assumptions and limitations

The main assumptions and limitations identified as part of the study included the following:

While the study aims to evaluate the barriers, opportunities and measures required to bridge the gaps to overcome barriers in platinum mining, the research is limited to a case study of a single platinum mining company. The company is a globally recognised mining company and the first mining company in South Africa (with one operation in Zimbabwe) that has formally established a goal of achieving ZW2L. This limitation is however alleviated by incorporating the mines, concentrators, smelters and refineries of this particular case study into the research. This should provide for results that are representative of the mining industry in general.

The documents utilised during the actual document analysis was limited to electronic document sources, but comprised both externally published as well as unpublished information, documents and graphs related to the specific case study. The information utilised has gone through independent assurance audits and it is therefore assumed that the information is accurate and representative.

Although the research was not limited to electronic publications only, the majority of the references used was accessed via the on-line NWU library and utilising peer-reviewed publications for this research to ensure accuracy of existing information referenced.

The semi-structured interviews were limited to individuals that were actively involved in the ZW2L drive and implementation and it is therefore assumed that their hands-on experience should provide for an accurate reflection on the barriers, opportunities and actions required to achieve ZW2L.

3.7 Chapter summary

A summary of this chapter is contained in Table 3-4.

Table 3-4. Data gathering, analysis and presentation process.

<table>
<tr><th>Data collection</th><th>Data analysis</th><th>Presentation of data</th></tr>
<tr><td>Document analysis: Evaluation of annual reports, monthly waste performance figures and site specific ZW2L strategy reports to gather trends, individual waste streams and related ZW2L off-take information.</td><td>Identification of key words and clustering into five ZW2L factors, followed by further clustering into barriers, opportunities and actions to align with research objective.</td><td rowspan="2">Case study findings from the document analysis and semi-structured interviews and how it relates back to literature review is covered in sections 4.2 (barriers) and 4.3 (opportunities), while the actions to address the barriers identified in 4.2 are presented in section 4.4 (actions to address barriers). These findings are then discussed under each of the five consolidated ZW2L headings, namely:
• Legislative
• Financial
• Infrastructure/Technology
• Human related
• Environmental</td></tr>
<tr><td>Interviews: Interviews were held with appointed waste champions, head of environment, group principle for product stewardship, environmental managers, representative of the appointed ZW2L partner and Supply Chain resource dedicated to ZW2L.

This will be to gain an understanding from individuals on the reasons for the trends and spikes derived from the document analysis and share barriers,</td><td>Notes and recordings made during semi-structured interviews were analysed to identify barriers, opportunities and actions to bridge gaps related to each of the five consolidated ZW2L factors from individuals’ experiences.</td></tr>
</table>

opportunities and actions taken based on their own ZW2L experience.		

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Introduction

This chapter covers the analysis, interpretation and discussion of data obtained from the document analysis and semi-structured interviews. The discussion will also illustrate how the data obtained from the document analysis was utilised to elaborate and contribute during the semi-structured interviews and discussions held with individuals in identifying the barriers, opportunities and actions taken by AAP in their ZW2L drive. In order to close the loop, the barriers, opportunities and actions identified in this case study are compared with those discussed in Chapter 2 (literature review).

4.2 ZW2L barriers identified in the case study

4.2.1 Legislative barriers

The document analysis that was undertaken in this case study, positively identified legislative factors as barriers to implement and achieve ZW2L, while nine out of the fifteen interviewees identified it as a barrier.

During the document analysis it was identified that AAP sold certain assets to a 3rd party mining company in 2016. Prior to the sale, all the Rustenburg mines, concentrators and the process operations made use of a single waste transfer station for sorting, re-use and recycling, but this licensed facility was included in the sale to the third party. In order to ensure sorting of waste to meet the ZW2L off-take requirements, a similar facility was required for Operations 4, 5 and 6, but a facility of this nature required a waste management license in line with the NEM: WA requirements at the time (Van Helsdingen, 2016). It may however be argued that this barrier was caused by human factors linked to poor planning, which could potentially have eliminated the legislative barrier in this particular example. The actions taken to address this specific barrier is covered in section 4.4.1 (addressing legislative barriers) and illustrates how the change in behavioural aspects (human factor barrier) could have eliminated the legislative barrier.

Another legislative barrier that was identified when the step change in the case study's ZW2L figures took place in 2017 (AAP, 2020:55), was the requirements of Government Notice Regulation 634 (GN R634). GN R 634 requires that individual waste streams be classified and safety data sheets (SDS) be developed for streams classified as hazardous waste. Table 4-1 contains a breakdown of all the individual hazardous as well as non-hazardous waste streams identified by AAP, will all hazardous waste streams requiring SDS. In order to overcome the

technological barrier caused by mixed waste as covered in 4.2.3 (infrastructure and technology barriers), further sorting of mixed waste into individual streams was required as discussed in 4.4.3 (addressing infrastructure and technology barriers). This resulted in more waste streams that had to be assessed to comply with the requirements of GN R634, prior to implementing the individual ZW2L off-takes. Interviewee 11 highlighted that one of the biggest challenges was to ensure SDS were in place and that the various third party off-take facilities are compliant with legal requirements in terms of licensing and authorisations.

Table 4-1. Breakdown of hazardous and non-hazardous waste streams identified by AAP.

Hazardous waste streams				Non-hazardous waste streams			
Contaminated sand blasting grid	Empty copper sulphate reagent bags	Oil/water sludge mixtures	Various empty plastic chemical containers	Garden waste	Kitchen fat and oil	Food waste	Graphite blocks
Lab crucibles	Hydrocarbon contaminated waste (soil, absorbent, wood, stone etc.)	Expired/redundant chemicals (various)	Contaminated soil (metals and salts)	Furnace and boiler bricks	Non-recyclable general/domestic waste (once recyclables removed)	Various empty product bags (non-hazardous)	Clean soil
Paint	Empty paint containers (plastic & steel)	Used grease	Sodium chloride	Used PPE (clean)	Scrap Steel	Canvas sheets	Polystyrene
Thinners	Empty aerosol cans	Oily rags	Asphalt bags	Cardboard	PVC pipes	HDPE pipes	Used steel containers (empty and

							free from residues)
Sewage plant screenings	Sewage sludge	Mudgun clay	Nickel filter cloths	Triple rinsed lab glassware	Clean building rubble	Vehicle Air filters	Clean wood waste (eg. pallets)
Used oil (hydraulic, lubricating, PCB etc)	Laboratory chemicals	Baghouse filter bags	Used filters (oil, diesel and petrol)	Plastic hoses	Rubber waste	Conveyor belt	Plastic pallets
Lead monoxide flux residue and empty bags	Fire-assay flux residue and empty bags	Used ceramics	Electronic waste	Window glass	Windscreen glass	Paper	Aliminium
Used batteries	Fluorescent tubes and bulbs	Soda Ash	Nickel contaminated wood pallets	Plastic from packaging	Used cargo nets	Electrical/copper cables	Used office furniture
Hydraulic hoses	Fibreglass waste	Zeolites	Used paint brushes, rollers and trays				

Mineral wool/lagging waste	Asbestos	Used/contaminated Personal Protective Equipment (PPE)	Redundant cleaning agents	
Spent Vanadium pentoxide catalyst	Waste contaminated with sulphuric acid	Lead liners and lead contaminated bricks	Base emulsion (Ammonium nitrate)	
Evapco fillers	Grease capsules	Larox plant residues	Spent activated carbon waste	
Medical waste	Bio-hazardous (Covid) waste	Sanitary waste	Tyres	

Another legislative barrier identified specifically through the document analysis was related to asbestos waste. Although no asbestos is used in any of the mining, concentrating or processing activities, there are instances where infrastructure of historical nature made from asbestos are present on some sites. Due to the health-related risks of asbestos, the re-use and recycling thereof is prohibited and disposal to a hazardous waste landfill is the only acceptable management measure for asbestos waste. In this particular case study this asbestos related legislative barriers was overcome by stipulating in the overarching ZW2L strategy (Interwaste, 2019) that asbestos related waste will be excluded from the ZW2L targets and ultimate achievement. Should asbestos waste be generated due to demolition of buildings for example, it will be recorded but will not impact on the ZW2L status as a whole.

An interesting observation made, related specifically to the case study's operation located in Zimbabwe, was how technological barriers, indirectly resulted in legislative barriers. There might be a valid argument for hybrid barriers, but seeing that the lack of technology was the root cause, it is discussed as such in section 4.2.3 (infrastructure and technological barriers). There might also be an argument to include "location" as an additional factor to be considered when identifying ZW2L barriers and opportunities, but once again the results fall back on barriers related to legislative differences between countries or in this case international law. Due to the lack of available ZW2L technology in Zimbabwe, the option of sending waste to South Africa were considered, however requirements related to the Basel Convention need to be considered for transboundary movement of hazardous waste streams, resulting in a legislative barrier for Zimbabwe based operations.

A key message and phrase that was highlighted during several of the semi-structured interviews was "*legislation did not prevent the implementation of ZW2L but was a barrier in implementing more preferred alternatives aligned with the waste management hierarchy*" which was further identified as a potential threat to the long term ZW2L sustainability. A specific example highlighted by interviewee 6, is where the opportunity to re-process contaminated soil as part of pollution control dam rehabilitation activities would have resulted in not only the avoidance of the waste, but also had financial opportunities as discussed in section 4.3.2 (financial opportunities). In order for the re-processing to take place, a dedicated facility was required to enable temporary storage of the material and blending with ore before being fed into the concentrator. Unfortunately, the required facility triggered some activities in line with Government Notice Regulation 327, resulting in the specific opportunity being lost due to timing required for obtaining the necessary Environmental Authorisation. This example illustrates and aligns with the finding from the literature review of how legislation can be counter-productive and described by Bosman *et al*. (2018:1093) as an "unintended consequence" by the legislation in question.

Another interesting view on legislative barriers identified by interviewees 8 and 11, was the lack of legislation in order to support and drive the ZW2L approach with the specific example being the lack of landfill related taxes as an incentive to divert waste away from landfill. Based on the outcome of the literature review in section 2.3, there is evidence of clear and well-developed legal frameworks for both South Africa and Zimbabwe to support a ZW2L approach from a financial incentive point of view, which contradicts the view of the interviewees. It may be argued that it is not the legislation itself, but the enforcement thereof that is lacking, which is supported by UNEP (2018:55), as covered under section 2.4.1 of the literature review, stating that the waste management in South Africa provides a framework for successful IWM, but that enforcement is a serious gap.

The above observations and outcomes from the document analysis and semi-structured interviews are aligned with observations made in section 2.4.1 of the literature review, with De Jesus & Mendonca (2018:82) stating that in as much as legislation plays a role in driving change, it can also limit the implementation of ZW2L.

4.2.2 Financial barriers

A clear theme identified during both the document analysis and semi-structured interviews was the increased costs related to transport, handling and treatment costs of ZW2L off-takes vs disposal to landfill, with twelve out of the fifteen interviewees highlighting this as a barrier.

The increase in transport and treatment costs were especially true for the non-hazardous waste portion of the waste due to two main reasons, namely:

- In the case study it was found that prior to the ZW2L drive, the individual operations disposed of their non-hazardous at landfill facilities that belong to the local municipalities in which they operate. These landfill facilities are often located in close proximity to the location of these individual operations, which result in low transport related cost charges by the relevant waste management contractors.
- Access and disposal at these facilities are in majority of cases free of charge and where charges do apply, these are relatively cheap.

The technology identified for the ZW2L off-takes related to the non-recyclable, non-hazardous portion of waste, more often than not requires transport to the Gauteng region, resulting in a significant increase in transport cost. A typical example is Operation 7 that previously travelled in the region of 20km to the nearest landfill, but with the ZW2L drive the distance increased to 340km, with the nearest Refuse Derived Fuel (RDF) facility located in Germiston. Another

example is Operation 1 that operated their own landfill, but is now required to transport waste for a distance of over 300km in order to enable ZW2L off-take.

The option of utilising the non-recyclable, non-hazardous waste portion in the RDF facility requires some preparation and further fine sorting to ensure the desired mix can be obtained to meet calorific value requirements. The resulting bales and compressed briquettes from the RDF facility is then used as alternative fuel sources in industrial applications. The cost associated with the RDF solution increased the costs for treatment of non-recyclable, non-hazardous waste by five-fold for Operations 4, 5 and 6, compared to using the municipal landfill facility for disposal (Van Helsdingen, 2019).

The implementation of ZW2L therefore required additional budget to be motivated for by certain operations, which may proof to not be an easy discussion, this is where human factors also played an important role.

The above results are aligned with findings from the literature review as covered in section 2.4.2, in which Grafström (2021:6), states that the implementation of ZW2L alternatives in some instances require excessive capital input and Rizos (2016:10), found that the lack of capital and business case is a barrier to move from a linear to a circular economy. From a Zimbabwean perspective, it is acknowledged that the lack of current financial incentives are a barrier in promoting re-use and recycling (ISWA, 2021).

4.2.3 Infrastructure and technological barriers

During the document analysis it was observed that stretch targets were established by AAP for operations to reach ZW2L by end July 2020, however it was observed that Operation 1 continued to contribute 77% of the case study's total waste to landfill in May 2020 and 60% in June 2020 (AAP, 2020). During the semi-structured interview with Interviewee 1, this observation was questioned and was attributed to the delay in completing construction of the centralised waste sorting facility. The need for this additional facility was identified based on learnings as AAP approached zero. The lack of an additional dedicated sorting facility was specifically identified as a barrier at Operation 1 and although construction commenced, it was delayed by the national lockdown caused by the Covid-19 pandemic.

The impact of Covid-19 cannot be ignored as it forced people to adjust to a new "normal". It changed the way we as people approach work, personal life, routine activities and travelling to name just a few. It can be argued that Covid-19, although not specifically a barrier on its own, was at the very least a contributing factor to some of the barriers identified in the AAP ZW2L drive.

The Covid-19 pandemic introduced new waste streams as various precautionary measures were implemented, which required off-takes to be identified and budget to be allocated to maintain the ZW2L status. These new streams were handled separately as a bio-hazardous waste and included the following:

- Straws used to blow into alcohol detectors at access gates
- Sanitary wipes used for biometric fingerprint readers at access gates
- Face masks worn in the operations

From the document analysis and resulting semi-structured interview, the technological barriers associated with Operation 10 stood out. Whereas identified technologies as ZW2L alternatives are available in South Africa, these technologies and facilities are not available in Zimbabwe. This added additional pressure on Operation 10, which is supported by the barriers identified during the literature review in which Kerdlap *et al*. (2019:15) indicates that the availability of dedicated material recovery facilities enable high rates of recycling. However, the actions taken to overcome these barriers as covered in section 4.4.3 (addressing infrastructure and technology barriers), not only successfully bridged the gap, but ensured that these barriers were turned into opportunities as discussed in section 4.3.3 (infrastructure and technology opportunities). Twelve out of the fifteen interviewees confirmed that they experienced infrastructure and technological barriers in achieving ZW2L.

Out of all the ZW2L barriers identified in the case study, it can be argued that the technological barriers remain the biggest threat to the sustainability of their ZW2L status, as there are five waste streams for which ZW2L off-takes have not yet been confirmed (Van Helsdingen, 2021), namely:

- Vanadium pentoxide (Operation 4)
- Zeolites (Operation 6)
- Base emulsion (Operation 9)
- Lead contaminated bricks (Operation 5)
- Fibreglass waste (Mostly related to Operations 4, 5 & 6)

The reason for including this under technology and infrastructure barrier, is due to the fact that technology has simply not yet been identified to enable diversion of these waste streams from landfill. During a discussion with Interviewee 8, the following was mentioned: "*Technology to handle especially hazardous waste in Zimbabwe, is simply very limited or not available*". Various investigations and trials are underway to identify sustainable solutions for these waste streams and are further discussed under section 4.4.3 (addressing infrastructure and technology barriers).

When comparing the outcomes of this study with the literature review in section 2.4.3, in which Godfrey & Oelofse (2017:6) states that South Africa face infrastructure challenges such as lack of transport, equipment and waste sorting and storage premises, it might be argued that although this was the case for Operation 1, it was an isolated situation, rather than the norm. From a South African government point of view, this literature review finding might be true, but from the case study perspective, it was the lack of available technology itself to enable ZW2L that was identified as the main technological barrier, resulting in five streams continuing to be sent to landfill and threatening the sustainability of ZW2L.

4.2.4 Human factor barriers

A recurring theme identified from both the document analysis and semi-structured interviews is the importance of awareness, with all fifteen individuals interviewed identifying human factors (lack of awareness, leadership, ownership and compliance) as one of the biggest ZW2L barriers. Without the necessary support, whether from top management or employees, ZW2L cannot be successful. The importance of leadership is supported by the literature review findings in which Singh *et al*. (2020:4) states that arguably one of the most important human factor barriers is the lack of decision making at the top management level.

The lack of awareness is the main cause for human factor barriers as identified in the case study, as this ultimately translates to a lack of support with the ZW2L implementation and lack of compliance related to at-source sorting for example. This lack of awareness as a key human factor barrier is supported by the literature review in which Govindan & Hasanagic, (2018:301) states that the barrier that appeared most often after consumer perception, was the lack of awareness of CE towards ZW2L. In this specific case study, the consumer perception barrier was not identified as this is mostly experienced by recycling companies themselves when attempting to sell recycled materials instead of virgin material.

One of the main observations made during the document analysis, was that the ZW2L journey only seemed to have kicked off in 2017 instead of 2013 (AAP, 2018). The 2016 total AAP waste sent to landfill was only 3% less than the total sent to landfill in 2013 with a big step change only taking place in 2017. By the end of 2017 there was a 42% reduction in total waste to landfill against the 2013 baseline, a trend that continued ever since and at the end of 2020, the case study achieved a 92% reduction in total waste sent to landfill against the 2013 baseline. The available 2021 case study data indicates that a total of 18.06 tons have been sent to landfill which is a 99.9% reduction against the 2013 baseline, with the waste sent to landfill in 2021 related to the “problematic” waste streams discussed in section 4.2.3 (infrastructure and technology

barriers). While undertaking the semi-structured interviews, the reason for this pattern was questioned and the data analysis revealed the following main reasons:

- Lack of ownership – No active drive and dedicated accountability to drive the ZW2L initiative from operational point of view.
- Lack of compliance related to implementation of at source sorting – unable to improve re-use and recycling opportunities
- Lack of detailed inventory of individual waste streams – unable to investigate ZW2L off-takes if individual streams are not known
- Lack of human resources – required to enable further sorting of waste at sorting facilities
- Failure to identify and understand opportunities related to ZW2L solutions – a specific example was related to Operation 6, where the decision was made to continue disposal of a specific waste stream to hazardous waste landfill rather than implementing the alternative option identified, namely thermal treatment, due to excessive costs. It might be argued that this should be covered under financial barriers, but it relates more to the lack of understanding and awareness, as further investigation resulted in surprising results confirming that a financial barrier did not exist in this case. This specific scenario is discussed in section 4.3.2 (financial opportunities), which goes to show that by bridging the human factor barrier through the creation of awareness, may open up other opportunities.

4.2.5 Environmental impact barriers

Only two out of the fifteen interviewees indicated that they experienced environmental impact barriers from the ZW2L drive in the case study. Both interviewees 5 and 8 identified the same environmental impact barrier during the semi-structured interviews as the concern of the environmental impacts associated with incineration of waste as a ZW2L option. The concerns raised by the two interviewees are aligned with section 2.4.5 of the literature review in which Kerdlap *et al*. (2019:16) use the example of treating electronic waste through pyrometallurgical methods which will result in toxic fumes, leading to air pollution. This also relates back to section 4.2.3 (infrastructure and technology barriers) whereby a small-scale incinerator was installed at Operation 10 as a result of the unavailability of alternative ZW2L technologies in Zimbabwe. As mentioned by both interviewees, this is not so much a barrier to achieve ZW2L, but a barrier towards the long-term sustainability thereof and making it important to further investigate alternative options, with Interviewee 8 concluding with a rhetoric question: "*Is the resulting impact better or worse than waste disposal?*".

The counter argument discussed in section 4.3.3 (infrastructure and technology opportunities) is that the incinerator being utilised have abatement equipment in place to meet legislated limits and

when compared to long term effects related to landfills, is regarded as a more environmentally friendly and preferred solution to implement.

4.3 Opportunities identified by the case study in their ZW2L drive

4.3.1 Legislative opportunities

One of the key themes identified in terms of legislative opportunities in the case study, is the alignment with the literature review outcome related to the requirements of the National Waste Management Strategy (NWMS) and establishing a pro-active approach in terms of future ZW2L related legislation which is likely to be used as a command-and-control approach to support successful implementation of the NWMS. A typical example is the latest ban on disposal of liquid waste to landfill as well as waste that has a certain calorific value as provided for through the National Norms and Standards for the Disposal of Waste to Landfill (GN R 636 of 23 August 2013). By achieving ZW2L the need to establish new case study owned landfill facilities are eliminated, which would have required environmental authorisations in terms of licensing. The elimination of the need for these landfill facilities also have a financial opportunity as discussed in 4.3.2 (financial opportunities).

Overall, thirteen of the fifteen interviewees identified legislation as an opportunity to drive and achieve ZW2L. The legislation can be used as an opportunity to influence supply chain contracts to ensure that suppliers of goods and services support the case study's ZW2L drive and motivate suppliers to re-think waste management in their own internal processes as well. A total of six of the interviewees used the words "*future legislation*" and believes that this proactive ZW2L approach by the case study to align with South Africa's NWMS, created a future opportunity for a competitive advantage.

Another opportunity identified by AAP which is a result of waste related legislation, is the introduction of the GN R. 1184 related to Extended Producers Responsibility (ERP). ERP means that a producer's responsibility for an identified product is extended to the post -consumer stage of an identified product's life cycle (DFFE, 2021:4). ERP regulations have been published for the following sectors:

- Electrical and electronic equipment sector
- Lighting sector
- Paper and packaging

Although AAP have identified ZW2L off-takes for waste streams associated with these sectors, the ERP will support a potential move up the waste management hierarchy, for example, AAP

sends used fluorescent tubes to a third party for recycling purposes and reports it as a recycled stream, however if the waste is returned to the producer it in effect means that AAP eliminated the stream as a waste that requires to be dealt with internally in terms of recycling. There is however the need to ensure that producers deal with the waste in a responsible way. Through AAP supply chain department, the producers and suppliers of the products associated with the ERP regulations are being engaged to ensure they comply and are held to account for complying with the regulations. This is being achieved through the review of existing supply contracts.

During the document analysis, it was also evident that AAP circulated a formal pledge document to existing waste management contractors appointed by the individual sites, whereby these contractors declare their commitment to not only support the ZW2L drive but also ensure compliance with relevant legislation and support the 2012 NWMS in terms of the waste management hierarchy as highlighted by the following extracts (AAP:2019):

- *"Abide by all regulatory requirements and in particular the landfill disposal of waste under the National Norms and Standards for the Disposal of Waste to Landfill (GN R 636 of 23 August 2013), as well as the Regulator's taxation on the disposal of waste to landfill Department of Environmental Affairs' 2016 National Pricing Strategy for Waste Management".*
- *"Demonstrate the willingness and real time evidence that all waste streams have been evaluated and that a progressive, long term sustainable plan(s) / solution have been or will be implemented to prevent waste disposal to landfill".*

4.3.2 Financial opportunities

There is some irony in the theme identified for financial opportunities, as some of the biggest financial opportunities that were realised through the ZW2L implementation was a result of barriers and consequent need to implement actions (covered in 4.4.2) to overcome the barriers, which ultimately lead to opportunities, in other words, effectively turning barriers into opportunities. The competitive advantage as mentioned in section 4.3.1 is not only limited to setting the case study up to comply with potential future legislation changes, but as per the literature review this competitive advantage is also realised in terms of monetary value related to acquiring loans and capital from investors as per the literature review (Frederiksen, 2018:503).

As alluded to under section 4.2.4 (human factor barriers), the failure to identify and understand opportunities related to ZW2L solutions was identified as a barrier specific to Operation 6. The solutions to this barrier which is discussed in section 4.4.4 (addressing human factor barriers), resulted in a financial opportunity for this specific operation by turning an average R1 million cost

per annum into an estimated R17 million income opportunity, resulting in a net gain of around R16 million per annum (Van Helsdingen, 2018). This financial turnaround in itself went a long way to ensure a positive financial business case for implementing ZW2L for the case study as a whole.

Various by-products produced and managed as waste, was turned into a resource and associated financial income by selling these to third parties. Examples include sodium chloride and gypsum produced by Operation 6 and sodium sulphate produced by Operation 5. By adjusting some metallurgical settings in the process, the sodium sulphate quality was improved and the contract with customer amended to sell an additional 13000 tons of sodium sulphate per annum instead of disposal, resulting in an additional R25 million income per annum (Van Helsdingen, 2019).

Another example of how financial opportunities were realised due to the ZW2L drive was the establishment of a soil remediation facility at Operation 1. As per Interviewee 13: "*The bioremediation facility was commissioned in 2017 and resulted in a net saving of between R300 000 – R600 000 per month by bioremediating and re-using soil versus transport and disposal to landfill*".

The examples discussed illustrate how the business case considered from a holistic approach, instead of an individual operational perspective, resulted in a positive financial business case as discussed in section 4.4.2 (addressing financial barriers).

These examples identified in the case study are aligned with section 2.5.1 of the literature review which states that the revenue generated from recycling will contribute to cashflow (Matete and Trois, 2008:1490).

4.3.3 Infrastructure and technological opportunities

Once the individual waste streams and associated quantities per operation were identified as discussed in 4.4.4 (addressing human factor barriers), it opened the opportunity to investigate available technologies. From the document analysis and interviews it became clear that various ZW2L technologies were immediately available for implementation as off-takes, which included the following examples:

- Internal re-use and recycling opportunities for used flux pots, redundant taphole clay and used sand blasting slag
- Supply chain opportunities – establishing take-back contracts for used batteries, printer cartridges, used tyres, broken windscreens.
- Composting opportunities and available licensed facilities for garden and food waste;
- Recycling opportunities for sorted recyclables – paper, plastic, steel and glass;

- Blending platforms for used grease;
- Refuse Derived Fuel Facility for non-recyclable domestic waste and various hazardous waste streams with high calorific value;
- Facilities for soil and rubble treatment, recovery and re-use opportunities;
- Thermal pyrolysis and use of resulting carbon residue as alternative fuel sources or recovery opportunities like the low-grade combustible material at Operation 6 and;
- Incineration of unsorted hazardous waste as interim measure while infrastructure barriers as discussed in section 4.2.3, were addressed.

During the semi structured interview with interviewee 14, the following specific point was highlighted regarding incineration: "*Although incineration is implemented as a last resort to divert waste away from landfill, an incinerator equipped with abatement technology will result in less environmental impacts than poorly managed landfill facilities*". This comment was made against the backdrop of poorly managed landfill facilities that cause soil, water and air pollution, while also exposing people to safety and health risks through uncontrolled scavenging, sorting and settlement.

Although the technologies are readily available in South Africa, this was not the case for Operation 10 as discussed in section 4.2.3 (infrastructure and technology barriers). However, the actions taken to overcome the barriers as discussed in 4.4.3 (addressing infrastructure and technology barriers) resulted in other opportunities being realised associated with the biodigesters and other internal re-use and recycling opportunities identified. These opportunities realised are discussed in section 4.3.5 (environmental impact opportunities).

Another opportunity identified from trends during the semi-structured interviews, was that the ZW2L approach acted as a driving force for waste management infrastructure improvements to allow for better sorting facilities, roofs to protect recyclables from rain damage, acquiring equipment for example bailers and meeting requirements of the national norms and standards.

4.3.4 Human factor opportunities

From the document analysis conducted it was identified that one of the strategic pillars around which the case study's ZW2L strategy was developed, focused on community benefits. Several opportunities for community benefit were identified during the ZW2L drive, evident from both the document analysis and semi-structured interviews undertaken. The human factor opportunities realised however was not limited to external communities only, but also included opportunities to

ensure awareness and support from internal employees, which were key to the successful ZW2L drive.

In order to meet the requirements of the relevant ZW2L off-takes identified, intensified sorting of waste into more individual streams were required, which opened up an opportunity for people from surrounding communities to be employed by the operations and appointed waste contractors. As Interviewee 1 pointed out: "*By providing them with the necessary awareness, training and skills, it also empowers them to become ZW2L ambassadors in their own communities*". Local community members were also utilised by Operation 10 during the construction of the biodigesters and full-time job opportunities were created by appointing attendants from the local communities, for the operation of the incinerator and biodigesters.

Another initiative implemented at Operation 8, that created opportunities in communities was the donation of purpose-built bicycles to women involved in the recycling business. The donation of these purpose-built bicycles ensured that transport costs associated with the collection and delivery to recycling centres were eliminated, resulting in a higher monthly financial income and creating a more favourable business case for managing recyclable waste. As indicated by Interviewee 7: "*This created a viable alternative source for income for women that lost their source of income due to the Covid-19 pandemic*".

The above outcomes are aligned with section 2.5.2 of the literature review which states that the establishment of mines result in the establishment of businesses to support mining needs and that the opportunity presents itself to also identify entrepreneurs in surrounding communities to uplift them and address imbalances Nuur *et al*. (2018:108).

In 2018, the case study raised waste awareness through a "Waste to Art" competition for schools in the local communities surrounding its operations. Each operation chose a winner from their respective entries received and the winners from each operation was then invited to the grand finale that took place at AAP's corporate office in Johannesburg. This provided the children from these schools to showcase their work and many of them to experience a city environment for the first time in their lives, with cash prizes being awarded to the winning individuals and schools. This created awareness in communities on the value that can be attached to waste once waste is viewed as a resource.

From an internal human factor point of view, it was concluded from the semi-structured interviews that initial thoughts around the practicality and achievement of ZW2L was low, with some general managers being concerned about the targets being set as part of their operational key performance indicators. Interviewee 6 for example stated: "*As soon as they saw the initial*

results from the year-on year reduction, especially 2017 to 2018, it generated believe and soon the ZW2L drive was actively driven and supported by the general managers and employees".

These human factor opportunities are further aligned with section 2.5.2, which also found that by creating awareness and changing the human mindset around the value in waste, it will support the reduction, re-use and recycling of waste and at the same time provide local communities with job opportunities (ISWA, 2021).

4.3.5 Environmental impact opportunities

Except for the obvious opportunities in terms of a reduction in environmental impacts associated with landfills like loss of land, soil and groundwater pollution, air quality impacts from methane generation as a greenhouse gas and human health and safety impacts, several other opportunities for positive environmental impacts were realised by the case study, which became evident during the document analysis. This observation was also supported with the outcome of the semi-structured interviews, with all fifteen interviewees indicating that they experienced opportunities to reduce and eliminate environmental related impacts with the case study's ZW2L approach.

The case study calculated that the reduction in waste to landfill from 2013 to 2020, resulted in a reduction of around 500 000 tonnes of carbon dioxide equivalent (AAP, 2020:54). The renewable gas being generated by the biodigesters installed at Operation 10 is used as an alternative source of energy with the ability to generate 140kWh/day, while the resulting sludge can be used as compost during rehabilitation activities around the operation. This opportunity is aligned with the literature review which indicates that biodigesters can be utilised to convert organic waste into a sustainable energy source while reducing the generation of methane gas associated with landfills (Novus Print (Pty) Ltd t/a 3S Media, 2019:25).

The increased recycling and re-use of waste by both the case study and surrounding communities as a result of the awareness created through the ZW2L drive, requires less purchasing of new products which in turn relate to less natural and non-renewable resources being utilised for manufacturing of new products.

4.4 Actions identified from the case study to address ZW2L barriers

As is normally the case with the implementation of new initiatives in a company, it can be expected that certain barriers will be encountered along the way and the actions taken to then overcome these barriers are what will ultimately determine the successful implementation of the initiative in

order to meet the end goal. It is clear that the case study encountered several barriers as discussed in section 4.2 which required actions to be identified and implemented to be successful in their ZW2L journey. Sections 4.4.1 to 4.4.5 will cover the actions taken by the case study to bridge the gaps and overcome the barriers.

4.4.1 Addressing legislative barriers

During the semi-structured interviews with Interviewees 5, 6 and 9, it was indicated that to overcome the gap created by the divestment of the central waste transfer facility and avoid the lengthy process of applying for and constructing a new centralised waste transfer facility, a decision was made to utilise the existing on-site facilities and implement improvements for example construction of dedicated sorting bays within the existing facility, provide roofing over the sorting bays and obtain additional waste containers into which waste could be sorted directly to save up space. By utilising the existing facilities and upgrading them instead of expanding on the existing footprints or establishing a new facility, the need for licensing requirements was eliminated. This also allowed the opportunity to apply for a new centralised facility without delaying or even taking a few steps back on the ZW2L journey. The amendment of legislation, in particular introducing Government Notice Regulation (GN R 1093) in 2017 also assisted in overcoming the need to apply for licences for activities related to the sorting, shredding and bailing of waste, these are all activities that are important in the journey to divert waste away from landfill.

In order to overcome the lost opportunity of re-processing contaminated soil resulting from the pollution control dam rehabilitation in future, the case study applied for a centralised recovered concentrate facility to cater for temporary storage of material while blending and re-processing takes place. Interviewee 14 indicated: "*The environmental authorisation for the facility was received in December 2020, with construction planned to commence during the second half of 2021*". This action will not only overcome the barrier, but also result in a financial opportunity from the recovery of metals during re-processing, further strengthening the financial business case for ZW2L as discussed in section 4.3.2 (financial opportunities).

Following the identification of additional individual waste streams resulting from more intense sorting to meet various ZW2L off-take requirements, a third-party contractor was appointed to assist with performing the waste assessments and generate safety data sheets (SDS's) to ensure compliance with GN R634.

When the Basel Convention was identified as a legislative barrier against the option of sending waste from Zimbabwe to South Africa in order to gain access to ZW2L technologies, certain actions were implemented to overcome the technological barriers as covered in section 4.4.3

(addressing infrastructure and technology barriers). The development of the integrated solid waste management plan in Zimbabwe as covered in the literature review, will support this move up the waste management hierarchy (EMA, 2014:5).

4.4.2 Addressing financial barriers

To initially overcome the financial barriers, the ZW2L strategy focused on what was called “low hanging fruit”, which related to ZW2L off-takes that were immediately available without a substantial increase in treatment cost versus landfill disposal cost. Once implemented, the strategic approach identified during the document analysis and semi-structured interviews was to develop a business case for ZW2L implementation. The approach taken was to consider the ZW2L business case for each individual operation, which resulted in some operations showing an increase in costs to implement ZW2L, while others presented net savings and additional income linked with ZW2L alternatives. In considering the holistic business case from a company perspective, the result was that the net savings and additional income outweighed the additional costs associated with ZW2L off-takes. The figures obtained from the document analysis indicated an annual saving of R32 million in avoided transport and disposal costs, while revenue generated from sales came to around R13 million per annum. Some of these financial opportunities realised are discussed in section 4.3.2. This positive business case was utilised to motivate and obtain the necessary financial support for the individual sites during annual budget planning to implement ZW2L.

In order to further reduce transport and treatment costs, a register was developed to identify waste avoidance opportunities for implementation through supply chain. Examples included contract negotiations for returning used PPE, certain packaging, used tyres, batteries and empty chemical containers back to suppliers.

It was also highlighted during the semi-structured interviews that a positive ZW2L business case is not limited to finances, but that the positive environmental impacts and socio-economic opportunities also contribute to the overall positive business case. The identification and creating awareness around the positive ZW2L business case also contributed to addressing some of the human factor barriers as discussed in section 4.4.4 (addressing human factor barriers).

The above observations from the case study are aligned with section 2.6.2 of the literature review in which Rizos (2016:14), indicates that an important enabler to overcome financial barriers towards ZW2L is company leadership that considers the circular economy as part of an integral part of their business model.

4.4.3 Addressing infrastructure and technological barriers

In order to ensure more effective and efficient at-source sorting of individual waste streams, a corporate guideline for colour coded wheelie bins was developed for implementation by the individual operations. By providing colour-coded bins for individual waste streams, the at-source sorting of waste ensures that waste streams meet the criteria for the relevant ZW2L off-takes.

The establishment of the soil remediation facility at Operation 1 and completion of the centralised waste sorting and transfer facility post the initial Covid-19 pandemic lockdown, ensured that the operation could significantly reduce their total waste to landfill. Prior to finalisation of the dedicated sorting facility during the third quarter of 2020, the average waste to landfill from Operation 1 was 158 tons per month, which reduced to 11 tons per month and ultimately reaching zero.

Although the unavailability of ZW2L technology proved to be a barrier in Zimbabwe, Operation 10 took initiative and identified various ways in dealing with their waste through internal infrastructure and technology development. During the document analysis it was established that Operation 10 implemented at source sorting through colour coded wheelie bins aligned with the corporate guideline, provided sorting cages at the accommodation camps, installed biodigesters for organic waste and commissioned a small-scale incinerator for waste streams without any other ZW2L off-take opportunities. By implementing these actions, the operation did not only address their barriers but also realised other opportunities as discussed in sections 4.3.4 (infrastructure and technology opportunities) and 4.3.5 (human factor opportunities). It was also identified during the semi-structured interview with Interviewee 8, that various existing internal infrastructure and technology are being utilised for some waste streams, which include utilising combustible waste as an alternative resource in the smelter ladle preparation, crushing and smelting of used flux pots in the smelter furnace and using paper waste as an alternative tamping material for explosives underground.

The Zimbabwean situation is supported by section 2.6.3 of the literature review which states that from a Zimbabwean perspective, it is acknowledged that recycling needs to be a part of a holistic strategy to be successful (ISWA, 2021) and that the availability of infrastructure and technology plays an important role in this regard.

The internal solutions identified are however not limited to Operation 10, but other opportunities identified and implemented include used sandblasting sand being sent for re-processed through the Operation 4’s slag milling circuit, while redundant taphole clay and refractories from furnace rebuilds are crushed and returned to furnaces at Operations 3, 4 and 7.

The five “problematic” waste streams identified and discussed in 4.2.3 are a result of the unavailability of technology to either deal with these waste streams or replace it with substances that do have available ZW2L off-takes identified. The case study identified infrastructure and technology as one of the key areas for further investigation to ensure long term ZW2L sustainability and in an attempt to address the problematic waste streams, engagements with suppliers of the base emulsion, zeolites and vanadium pentoxide are on-going to investigate potential take-back arrangements. The potential of re-processing of vanadium pentoxide and zeolites through the smelter furnace is also being investigated. Trials on the recovery of vanadium from the vanadium pentoxide did not yield favourable results to make this a viable option. The fibreglass waste is currently undergoing trials through downsizing and feeding as an alternative fuel source into cement kilns, with these trials and associated emission testing planned to be completed by end September 2021 (Van Helsdingen, 2021).

The need for identification and implementation of site specific and external infrastructure and technologies to address the barriers identified in the case study is supported by the literature review, whereby DEFF (2020:52) in response to these barriers are engaging on the establishment of the following technologies:

- Biological Treatment (Anaerobic Digestion / Fluidised Bed Reactors);
- Material Recovery Facilities and palletisation;
- Composting and re-use of household biomass;
- Waste-to-Energy plants;
- Pyrolysis; and
- the use of ash, sludge and animal matter as a soil ameliorant and input to high agricultural production land.

4.4.4 Addressing human factor barriers

The actions taken to overcome each of the points discussed in section 4.2.4 (human factor barriers) are outlined below, with the need to create awareness identified as a common theme.

Lack of ownership – It is evident from the document analysis and semi-structured interviews that the support and drive from the Chief Executive Officer (CEO) and relevant Executives was a key requirement to the successful implementation of ZW2L in the case study. The ZW2L messages from the office of the CEO was a powerful motivator and annual ZW2L targets were incorporated into the KPI’s of each GM. These KPI’s cascaded down to the respective departmental heads to take ownership of reaching ZW2L targets. A template for appointing site-specific waste champions was developed and each GM appointed a designated waste champion to coordinate

the ZW2L implementation (AAPb, 2019). Once inventories were updated and off-takes identified, meaningful ZW2L targets were developed and discussed with each GM for acceptance and sign-off, this approach contributed to GM's believing that ZW2L targets can be met as it was based on evidence and facts, which then turned into opportunities as discussed in section 4.3.4. Individual operations were further encouraged by introducing AAP company-wide quarterly ZW2L competitions and setting up rules for certifying individual operations that meets the criteria to be certified as having achieved ZW2L. The above contributed to a strong ownership drive and in the words of Interviewee 14: "*GM's love competition and always want to win*".

Lack of compliance related to at-source sorting, re-use and recycling – The individual operations indicated during the semi-structured interviews that various actions were taken to overcome this barrier by increasing employee and contractor awareness through ZW2L roadshows, talk topics, ZW2L awareness training and updating of site-specific induction videos to include ZW2L. The quarterly ZW2L competitions were also drivers to increase awareness and compliance by individuals, while the operational specific waste management contractors were required to sign a pledge (AAPc, 2019), whereby they commit to support AAP's ZW2L drive and provide ZW2L training to their employees.

Lack of detailed waste inventories – In 2018, a specialist waste management company was appointed as a ZW2L partner, with the main purpose to assist operations with identifying individual waste streams, develop waste inventories and identify relevant ZW2L off-takes for the individual waste streams. The ZW2L partner had one-on-one engagements with individual operations and developed detailed waste inventories for each operation, which enabled the next step which was to identify the ZW2L off-takes. It is clear from the case study evidence that without the necessary awareness and inventories of each individual waste stream produced, relevant ZW2L opportunities in terms of avoidance, re-use, recycling and treatment cannot be identified.

Lack of human resources – The additional sorting requirements to meet criteria of the various ZW2L off-takes, required the appointment of additional sorters. The appointment of additional sorters was also identified as a human factor opportunity as discussed in section 4.3.4.

Failure to identify and understand opportunities related to ZW2L solutions – The low-grade combustible material was the main contributor of waste to landfill quantities at Operation 6. Disposal was the preferred option as it was much cheaper than thermal treatment of the material. During the semi structured interview with Interviewee 5, it was identified that the environmental manager engaged the GM, technical team, on-site environmental team and representatives of the thermal beneficiation company. Following a trial and detailed analysis of the ash resulting

from the thermal beneficiation process that could be returned to the operation for re-processing, it turned into a great financial opportunity as discussed in section 4.3.2. This illustrates the importance of engagement and creating awareness around the business case with regards to potential recoveries and benefits.

The case study outcome and measures taken have a clear alignment with the approach required as outlined in section 2.6.4 of the literature review, in which Gjetley and Pierre (2003:222) found that various measures may be utilised to increase awareness and that active participation in activities allow employees to get involved and take ownership.

The case study also undertook a ZW2L visit to the United Kingdom and France in 2018 to benchmark their approach against best practice by visiting and interviewing companies and industry that have achieved ZW2L. During the semi-structured interview with Interviewee 14, it was identified that one of the GM's was also invited on the trip, which created valuable awareness on the ZW2L opportunities and the realisation that ZW2L is achievable, a message that was successfully relayed to his peers once the party returned to South Africa. Whereas the benchmarking in this case study assisted in creating awareness, it was noted in section 2.6.3 of the literature review, which is related to addressing technological and infrastructure barriers, that benchmarking can result in the gaining of valuable knowledge about available ZW2L technologies to overcome technological barriers (Gjetley and Pierre, 2003:223). It can be argued that the benchmarking undertaken by the case study did not only assist in creating awareness, but provided an insight on an international scale of the ZW2L approach.

4.4.5 Addressing environmental impact barriers

As discussed in section 4.2.5, the environmental impact barrier identified in relation to the case study's ZW2L drive is related to the incineration of waste. To minimise the amount of waste required to be incinerated, it is important to enhance the at-source sorting as well as further fine sorting at the dedicated on-site waste sorting and transfer facilities to maximise re-use and recycling opportunities.

The case study's supply chain department is also playing an important role and dedicated a specific resource to support the environmental team with the ZW2L implementation and sustainability. Through the involvement of supply chain, opportunities will not only be limited to waste streams being incinerated but also identify opportunities for other waste streams currently being recycled or re-used to move further up the waste management hierarchy. Interviewee 12 indicated: "*Supply Chain is investigating opportunities for buy-back and alternative packaging materials to reduce the amount of waste entering the company*".

This approach will ensure a move in the right direction in relation to the waste management hierarchy and is aligned with section 2.6.5 of the literature review which warns against implementing alternatives that merely shift environmental impact potential from one sphere of the environment to another (Kerdlap *et al*. 2019:16).

4.5 Chapter summary

From the case study it is clear that human related factors was identified as one of the biggest barriers in the ZW2L drive, which was centred around lack of awareness, lack of compliance, lack of responsibility and support. Financial barriers, mainly due to increased treatment cost to achieve ZW2L was identified as an important barrier but was ultimately outweighed by the financial opportunities and positive business case for the case study.

The stand-out opportunity identified during this case study was the environmental benefits associated with the ZW2L drive through the elimination of land needs for landfill establishment and associated environmental impacts in terms of air, soil and water pollution. This coupled with the human factor opportunities, namely positive social impacts were also considered in the overall business case in this particular case study and not limited to the financial business case, which is an important learning to consider the holistic picture when driving ZW2L.

A positive observation from the case study is that actions to bridge the gaps were identified and successfully implemented to address majority of the barriers identified in driving ZW2L.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter will be used to summarise the link illustrated in chapter 4, between the research outcome and the initial research question posed in section 1.3, summarise how the findings from the case study relate to the literature review and how this research contributes to existing knowledge. The chapter will be closed out by discussing recommendations for future research.

5.2 Conclusions

When considering the main results and discussions contained in chapter 4, it can be concluded that the research question, namely: "*What barriers and opportunities may influence the implementation of the zero waste to landfill goal in the platinum mining industry?*", was successfully answered. This was achieved by ensuring that the three main research objectives were discussed, namely:

- Identify barriers to zero waste to landfill implementation;
- Identify opportunities from the zero waste to landfill implementation; and
- Identify measures required to bridge the gaps to overcome barriers;

The above research objectives were focussed on by covering each objective under its own dedicated subheadings during the literature review in chapter 2, making it the main focus during the document analysis and semi-structured interviews as per chapter 3 and by covering each of the objectives once again through sub headings in chapter 4.

By reviewing the relationship between this Southern Africa platinum mining case study and the findings from the literature review, there are clear evidence of similarities in the barriers, opportunities and actions taken to bridge gaps in driving ZW2L. Surprisingly the one area where the literature review findings differ from the evidence gathered from this case study, is on the availability of technology as described in section 4.2.3. Whereas the literature review (Godfrey & Oelofse, 2017:6) provided arguments for lack of transport and available technology, the evidence gathered from this platinum mining case study did not indicate any transport related barriers as contributing to technological barriers and that ZW2L technologies were readily available for majority of the waste streams in the South African mining context. It is however acknowledged that from a Southern Africa perspective, particularly Zimbabwe as per this case study, that technological barriers were indeed encountered. It is further also acknowledged that the remaining five problematic waste streams identified in the platinum mining case study, supports the view that additional technology is required to provide more ZW2L opportunities.

Although the ZW2L opportunities in the literature review were limited to environmental, financial and human factors, it was possible, through the document analysis and semi-structured interviews in the platinum mining case study, to identify opportunities related to not only financial, environmental and social factors, but also technological and legislative opportunities. Ironically, there are various instances where the actions taken to overcome a barrier, turned out to not only be successful in addressing the barrier, but resulted in ZW2L opportunities being identified and realised. The case study also indicated the importance of building the business case on not only financial considerations, but also social and environmental considerations, which has a clear link back to the literature review, in particular Figure 2-2, which illustrated the alignment with the pillars of the sustainability framework.

Another interesting observation as described in section 4.4.4, is that the literature review (Gjetley and Pierre, 2003:223), identified benchmarking against other industries as a way to bridge the gaps associated with infrastructure and technology barriers, whereas it became clear from the

platinum mining case study that benchmarking was identified as a valuable means of addressing the human factor barriers. It may be argued that both drives a similar goal, whether it is to change behaviour or understand what technology is available, it comes down to the creation of awareness.

By comparing content contained in sections 4.2 and 4.3, it becomes evident that the platinum mining case study considered the five main factors, with exception of the human factors, to be more opportunities in the ZW2L drive than they are barriers, as the opportunities related to these ZW2L factors were realised by addressing the barriers. This is a significant observation as it might be argued that this is an outcome of the successful implementation of ZW2L in this particular case study and with these individuals being directly involved, experienced first-hand that barriers can be overcome and even turned into opportunities, making ZW2L a realistic goal from a Southern Africa platinum mining perspective with the relevant support and dedication.

From the literature review undertaken, it is acknowledged by Singh *et al*. (2020:2), that although there are literature available that covers barriers to adoption of circular business models, the availability of literature is limited with specific reference to a mining industry perspective. This creates an opportunity for this particular case study, focusing on the non-mineral waste from mining, to contribute and add value to broaden existing knowledge and expand on the limited available literature. Although the study focused on platinum mining in a Southern Africa context, the fact that this particular case study focused on the full production chain, namely mining, concentrating, smelting and refining, it contributes to existing knowledge that can add value to Southern African mines focusing on commodities other than platinum. Certain Southern Africa metallurgical industries may also derive value from this particular case study as it can be argued that the platinum smelting and especially refining processes are aligned with these industries. As identified in this case study, even on the scale of Southern Africa (South Africa versus Zimbabwe), location or country can significantly influence the infrastructure and technology factors, where some countries and regions will identify this factor as a barrier, while other will identify it as an opportunity based on its availability. This is further supported by the alignment between the factors identified from the literature review and this particular case study and may therefore be argued that the barriers, opportunities and actions taken to bridge the gaps in driving ZW2L will be applicable to mining in general on a global scale, with the location ultimately being the deciding factor between a factor being identified as a barrier versus an opportunity.

5.3 Recommendations and areas of future research

In terms of this specific case study, it is clear that further research is required to overcome the technological barriers related to the five remaining problematic waste streams. It is evident from both the literature review and this particular case study that the dependence on infrastructure and technology points to a focus of re-use and recycling and although this is definitely a step in the right direction opposed to landfilling, opportunities to move further up the waste management hierarchy with a focus on waste avoidance is required. ZW2L is the pre-cursor for zero waste and future research on how mines can achieve zero waste will add value in understanding the approach required to drive a sustainable, circular economy.

An opportunity for future research identified during one of the semi-structured interviews was the opportunity to investigate an automated early warning system that identify any new or additional waste streams that might be introduced through new projects or changes to mining technology and confirm if current ZW2L measures and available capacities will cater for these. This provides an opportunity to research and develop a system that links digitalisation with waste management.

Another potential area for future research is to understand the Covid-19 related impacts on overall waste management and sustainability of ZW2L in companies where it has already been implemented. Covid-19 induced impacts may include unavailability or lack of access to technology during level 5 lockdowns impacts, introduction of new and additional waste through the use of face masks and sanitary wipes and sanitisers. It will also be interesting to see if the focus on the pandemic had any influence on the focus, awareness and compliance with existing ZW2L programs.

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ANNEXURE A

Semi-structured interview questionnaire

1. Demographic data

i. Name of operation:
ii. Province and country of operation:
iii. What is your designation:
iv. What is your relation to the AAP ZW2L drive (Indicate with X below)?

Appointed waste champion	
ZW2L partner representative	
Group Principal Product Stewardship	
Lead Environment: Platinum	
Environmental Manager	

2. Barriers and opportunities related to the ZW2L drive

Which of the following factors were identified as barriers and/or opportunities?

Factors	Mark with "X"				
	Barrier	Opportunity	Both (Barrier & Opportunity)	Neither barrier, nor opportunity	Elaborate
Legislative[1]					
Financial[2]					
Infrastructure and Technological[3]					
Human factors[4]					
Environmental impacts[5]					

3. Actions taken to overcome barriers associated with factors.

For factors that barriers were identified in point 2, indicate which actions were taken to overcome these.

Barrier category	Actions to address barriers
Legislative	
Financial	
Infrastructure and Technological	
Human factors	
Environmental impacts	

[1] Regulatory requirements that support or are counter-productive in driving ZW2L
[2] Financial related costs and/or income related to ZW2L drive
[3] Availability and access /unavailability of infrastructure and technology that allows for waste sorting, re-use, recycling and treatment
[4] Includes the presence or lack of awareness, support, drive and community impacts and/or opportunities related to ZW2L drive
[5] Environmental impacts and/or benefits related to ZW2L drive