Circular Economy: A Sustainable Approach to Waste Management in the City of Johannesburg

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Abstract Circular Economy (CE) is a fresh approach to a systematic waste management strategy. It establishes principles which align with a net-zero waste agenda, promoting a sustainable environment, society, and economy. Furthermore, the concept aims to reduce carbon emissions by using waste as a resource. Johannesburg (JHB) is facing social and economic problems, which need effective waste management techniques. Current waste management methods implemented by the public sector are not sufficient in combating waste accumulated daily. As part of a comprehensive research into how systematic waste management strategies are implemented in other countries, a qualitative study was conducted. Pikitup was used as a case study, and empirical data from the interviews of experienced practitioners were used. An inductive approach provided explanations of the continuous interplay between theories, business proposals and real-life examples. To bridge the current research gap, benchmarking currently implemented methods in the JHB city to those of leading countries in CE allows for enhanced developments in terms of efficiency and sustainable living. The results further suggested that waste production is a serious problem that not only the country is dealing with but the entire world. Therefore, many barriers should be overcome, concerning the introduction of environmental policies, effective investments, and social inclusion. JHB city should ensure that CE is adaptable and flexible to the standards set out by government and private sector waste management service provider; guaranteeing the technical capacities to implement CE. The model should accommodate activities like the informal sector but boost the principles of sustainable development.

Keywords Circular economy · Pikitup · Sustainability · Technology-know-how · Waste management

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1 Introduction

There are 58.78 million people in the country of South Africa of which about 5.05 million reside in Johannesburg. Pikitup is the main Integrated Waste Management (IWM) service provider collecting around 1.4 million tons of waste a year of which 94,355 tons was diverted from landfills [21]. Only 6.7% of the waste collected is recycled which is a portrayal of some underlying issues within the municipal waste management industry. One resident in Johannesburg produces about 2.5 kg of waste per day.

The city of Johannesburg (CoJ) is facing a crisis with solid waste disposal and efficient management of waste. The current and traditional linear extract-produce-usedump waste model is unsustainable [17]. Johannesburg has 12 waste management depots, of which only four are landfills and have limited options on how to manage it.

South Africa generates millions of municipal solid waste annually of which 93% is unable to be diverted. This is primarily due to the lack of landfill space because of population growth as a result of urbanization for better job opportunities (Rasmeni and Madyira 2019). The diversion statistic alone is overly concerning not only for the city and the environment but, for its inhabitants as well. Non-recycled waste produces a wide range of toxins such as carbon gas emissions, heavy or rusty metals, pathogens, or radiation. Metropolitan cities such as Johannesburg are unable to easily license new landfill sites causing the remainder of the 4 landfill sites to pile up to maximum capacity. Waste that is not diverted, sorted, or recycled contributes to ongoing waste management practices creating a cause-and-effect chain reaction. Landfill sites that have reached maximum capacity have no other choice but to shut down their facilities. This presents room to introduce a new waste management strategy [23].

The research aims to implement and adopt the Circular Economy to help combat and mitigate waste collection on landfill sites. MacArthur Foundation [10] defines the Circular Economy (CE) as a design that uses the industrial system to restore and regenerate waste by promoting its useful life for the purpose of producing sustainable energy, the elimination of harmful chemicals by reusing or repurposing waste for a useful second life product. These factors give context and origin to modern construction, highlighting waste management strategies as enablers for greater adoption within the construction sector. The key aspects in applying the circular economy across a building's life cycle is the preservation of a building material's added value, by recirculating them to close their loops and manufacture new products. How waste can be implemented within the construction industry's adaptability through eco-bricking and eco-asphalt initiatives researched within this study to promote circularity.

2 Literature Review

Sustainable development (WCED) [25] was originally defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. But the issue that hinders this initiative is the traditional, linear output flow of materials and energy between nature and the human economy [17]. This output flow is running down the system in which it operates, from an ideal model. A system that does not recommend advancements of new forms of safe employment, encouraging the activities that are still in action (i.e. informal sector) and boosting the principles of sustainable development.

By critically considering the concept of CE from the perspective of sustainability, CE can be understood as an economy constructed using cyclical materials flows, renewable energy sources and recycling energy flows to provide innovative waste management solutions [18]. Successful CE contributes to economic, environmental, and social dimensions of sustainable development. And, according to CE, landfill disposal should be the last option.

2.1 Current Municipal Solid Waste Practices in the City of Johannesburg

According to the information available from the City of Johannesburg, the city produces approximately 1.7 million tons of waste per year which includes approximately 291,751 kg in the form of illegal dumping, 82,839 kg collected from the streets and only 568,893 kg of waste is diverted from the 4 landfill sites [21]. Pikitup's strategic focus is to reduce the amount of waste generated by providing sustainable and innovative waste management solutions, as well as keeping the city clean through the following initiatives:

- Waste collection services and separation at source—This strategy was implemented in 2009 to combat the strain on the city's landfill sites. Although the strategy initially envisaged the diversion of 120,000 tons of dry recyclables by 2018/19 (subject to budget availability), the current diversion targets have been revised to 40,000 tons in 2017/18, 50,000 tons in 2018/19 and 55,000 tons in 2019/20 in line with the current available resource.
- A Re Sebetseng campaign—Like the Uganda Campaign in Rwanda, the A Re Sebetseng campaign thrives to encourage the city's residents to take care of the environment, and seeks to promote a culture of reducing, reusing, and recycling waste [6]. The campaign is facilitated by Pikitup, but it is the responsibility of all councilors, city departments, and regional offices to drive the programme.
- Waste diversion from landfills strategies—Several strategies have been implemented in the city to avoid landfilling of waste, increasing available landfill airspace, reducing greenhouse gas emissions, prevention of ground contamination

and other landfill associated problems. Solutions such as waste buyback programs have been implemented.

Pikitup has been struggling to keep up with the volumes of waste produced within Johannesburg. With only four landfills and limited options on how to manage it, there is clearly room to introduce a new waste management strategy into the picture. The authors would like to introduce a new method of handling this waste while they strive for a greener future. There is a deficiency within the waste management system within Johannesburg, with a lack of technology, strategies, and facilities [14]. These deficiencies are detrimental to the environment through pollution. The authors may not be able to solve the problem but may be able to present an option to assist in mitigating this issue.

2.2 The Circular Economy (CE)

The circular economy is a concept that has slowly emerged as a greening tool and economic approach to waste management in many European countries attracting scholars, practitioners, and businesses alike.

From this, the authors can deduce that the circular economy is an economic and environmental concept that restores, regenerates, or revitalizes the use of a waste product's 'end-of-life', which is a shift from the conventional take-make-dispose model, by reducing the harmful toxins in waste through superior design concepts.

The CE restores primary materials into secondary reusable materials or energy through their visionary mission of innovative elimination of plastics through redesigning, reusing, recyclable or even compostable plastics [11]. Reusing waste reduces pollution and landfill waste, making it safer for the environment and a safer approach to sustainable development. Rather, the CE model embraces innovative concepts such as designing out waste and pursuing eco-effectiveness instead of eco-efficiency [15].

2.3 Comparison to European Countries

The implementation of principles concerning CE is intensifying in developed countries [16] while developing countries are still suffering inappropriate waste management due to the lack of economic funds, social/public awareness, and political will. The most common practice is the take-make-dispose approach which leads to unsuitable landfill conditions. The CE is a common waste management practice in developing countries.

The EU called for waste management to be transformed into sustainable material management which embeds the principles of the CE, enhancing the diffusion of renewable energy, increasing energy efficiency, reducing the dependence of the Union

on imported resources, to provide economic opportunities and long-term competitiveness [13]. As part of its Action Plan, the waste services are distributed between direct and indirect municipal companies, with some corporations owned by the municipalities [24]. Whereas, in most developing countries, municipal solid waste is handled by the municipalities proving unsuccessful and detrimental to the environment [20].

Given a clear focus from legislature, most EU countries plan on achieving full CE by 2030 by means of the following initiatives: waste to energy initiatives, active participation by residents, recycling, district heating, waste prevention, separation of waste and specific recycling circuits, Waste and Resource Action Programme (also known as WRAP) which aims at showing how businesses, organizations, and consumers can be part of a resource revolution. Waste to Energy is a well proven and preferred waste management practice in the EU and worldwide since it results in both the minimization of environmental impacts in landfilling and renewable energy generation [19]. Developing countries like China, Serbia and India have started to implement CE, because of low-middle income, they are introducing projects or management plans with no effective changes [12]. Thus, the reason of comparing JHB City with first-world countries. To see what improvements can be adopted (Table 1).

Table 1 Comparison of the city of Johannesburg to European countries

City	Waste generated (G) collected © and landfilled (L) in tons	IWM service provider (s)	Amount of waste diverted to landfills via CE
Johannesburg	G = 59 Million tons C = 69% of G L = 90% of G	CoJ municipality via Pikitup	Aim of study
Rotterdam	G = 500 kg per person per year C = 100% of G L = 3% of G	The municipality of Rotterdam	By 2030 the city wants circularity to become common practice, aiming to reduce primary resource use by 50%
Oslo	G = 321 kg per person per year C = 100% of G L = 3% of G	Local municipality and private entities	The city of Oslo has set an overall target to reduce its CO_2 emissions by 50% by 2030 and to become carbon neutral by 2050
London	G = 7 million tons C = 100% of G L = 20% of G	Local municipality	Plans for achieving net zero waste by 2026

3 Methodology

In order to execute this research, a case study approach was adopted, to obtain an in-depth appreciation of an issue, in its natural real-life context [22]. The case studied was Pikitup, JHB city's official waste management service provider. The primary data was collected using semi-structured interviews containing a mixture of open- and closed-ended questions, where participants were asked about the legal framework of South Africa allowing for the introduction of a new waste management strategy approach towards net zero waste. Whether JHB has the technological know-how of repurposing waste readily available and, can something new be produced from the waste in the loop of the CE? The aim was to provide a detailed holistic description that illuminates the participants' understanding of the CE initiative.

The inductive style used, aimed to generate meanings from the data set collected to identify patterns and relationships to build a theory by using the participants' views to build broader themes and generate a theoretical interconnection of themes [26]. The participants were selected based on their role in the waste management process and their familiarity with CE efforts. Using a non-probability, snowballing sampling technique [22], interviews were conducted with 3 waste minimization team's at Pikitup, 5 Pikitup regional managers across JHB, and 2 other recycling companies (*see* Fig. 1, *in* Sect. 4.1). This population was chosen based on the need to eliminate waste on landfill sites. The questions related to their experiences on how they controlled unexpected barriers of new waste management strategies currently implemented.

The CE is a relatively innovative concept in South Africa, and, in this study, it was important to obtain a detailed and comprehensive view on how the City of Johannesburg can implement the CE to improve existing waste management plans in the approach to net zero waste.

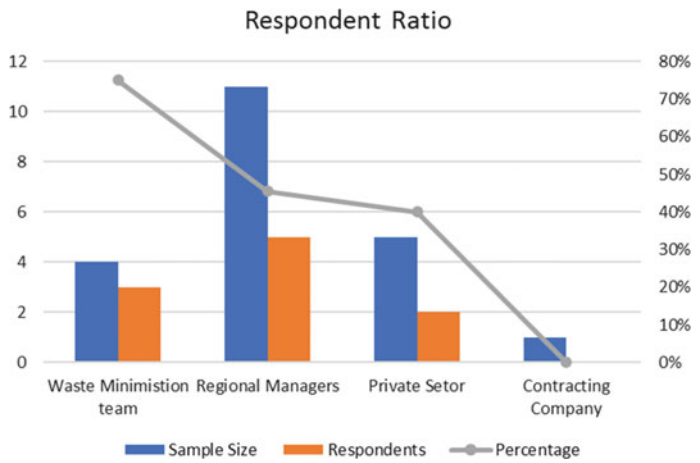

Fig. 1 A low respondent ratio due to Covid-19

4 Results and Discussion

4.1 Interview Analysis

Landfill disposal is the most preferred method for waste management. Respondents saw a need to have more options in either recycling or re-use, rather than straight disposal. From the anticipated sample size, a rather low respondent rate was achieved. During this research, most participants were not available, even through Zoom or on mobile calls. Based on the current respondent rate, the following information was established; that few people looked at the CE strategy as a business venture into having another form of recycling. They viewed CE as a process whereby waste is transformed into a new waste product often altering the products chemical characteristics, whilst others saw a waste economy solution that can benefit to solve common challenges—only collaboratively. This collaboration should be formed by the government, local municipalities, product retailers and other third parties. Figure 1 shows the poor response rate of the interviews, compared to the anticipated sample size. And the unwillingness of contracting companies to invest in recycling facilities.

4.2 Legal Framework

Currently, SA has a fragmented approach on waste management responsibilities. Participants from Pikitup had thought provoking responses. They pointed out that Pikitup sets out goals or corporate strategies that need to be met at the end of each year, however, these strategies have not been able to eradicate waste efficiently. Because many barriers still exist for developing CE strategies, there are no proper follow-up strategies on the progress. The SA government is not at the forefront in driving the legislation as it is in the EU. In the CoJ, Pikitup has only four active landfill sites. These land-fills sites cannot accommodate the daily waste intake that the city's inhabitants produce. The landfill sites have piled up to the point of no return, forcing a few landfills to shut down completely. The implementation of CE in European countries provides better waste management techniques that can move from over-packed landfill sites to not utilizing them at all. In SA, this solution would not only slowly and effectively reduce waste on landfill sites but would reduce the need for landfill sites. But, until collaboration between the government, municipalities, and the private sector to enhance the transition towards CE, improvements or plans such as converting waste-to-energy as fuel, addressing the issue of solid waste management will only be in the pipelines for solving over-packed landfill sites. The main tool is the introduction of reliable regulations/legislations that can support the development of the CE through sufficient economic support using public–private partnership, technical assistance, and international collaboration.

4.3 Technical Capacity

The choices of technology primarily depend on a country's income level. Technology is constantly evolving, and most countries do not rely on a single waste-to-energy technology but use multiple technological methods. When asked whether South Africa as a developing country has the technological-know-how to implement or adopt a new waste management benchmark, some respondents answered that it would be possible if knowledge sharing on recirculation and treatment solutions on technical facilities is made known, with awareness on improved social behaviors. But others felt that South Africa would not be able to accomplish this due to high electrical rates, grid interconnection costs and high capital start-up costs. However, technology industries, come in forms of choosing the most efficient and environmentally friendly type of technology.

From these responses, the researchers were able to deduce that although the CE is an international benchmark, the technique, knowledge, and strategy need to be adapted or adjusted according to the capabilities of the country. A new waste management benchmark "is not as challenging as one would think" said one respondent. 82% of the respondents had said that a new waste management strategy is possible, while 18% were skeptical. If the benchmark can benefit the country, economy, and environment, then it can be implemented with the necessary research and development said another respondent. Technology is ever evolving, and the implementation of the benchmark may take a while to implement however, people adapt easily to new ideas or concepts particularly now during the twenty-first century.

4.4 Role of the Private Sector

The private sector is a key sector in addressing the challenges of vulnerable communities, and it has much to contribute to the planning, development, and implementation of climate adaptation strategies, including sector-specific expertise, technology, efficiency, financing, and entrepreneurship [2]. A participant from Pikitup agreed with this statement stating that the private sector has more resources, technology and especially funds as municipal budgets are spread thin across other departments. Integrated waste management with all stakeholders is key to the successful implementation of the circular economy. Interviewees noted that the current strategy is effective, however this did not deliberate on the full scope of the challenges within the industry.

The issues relating to lack of integration between the government and the private sector delays the appropriate policy formulation and authority allocation. The obstacle of lack of communication, has caused slow progress in ensuring environmental safety and facility efficiency. Though these challenges are present, other respondents took the neutral route and stated that effectiveness should encompass

measures formulated with a multi-disciplinary approach. And there should be guidelines on comprehensiveness, consistency, and flexibility of the policies. Central to the CE in SA, is the informal waste pickers and dealing with illegal dumping within communities. CE should deal with poverty reduction and social inclusion. Informal waste pickers are responsible for a large part of the recycling activities, without a contribution to public financing. A participant stated that, the experience and knowledge of waste pickers can create more effectiveness in the CE. A successful implementation of the CE should adapt to the countries' needs.

From the results obtained above, the collaboration of the private and public sectors is vital to obtaining optimum results in waste management efficiency. Not only is it vital for their collaboration to succeed but it is just as important for this collaboration to take effect in ensuring the possible implementation of the CE which has been proven effective in countries abroad reducing waste all round.

4.5 Second Phase: Eco-Bricking and Eco Asphalt as a Circularity Solution in the City of Johannesburg

Factors affecting the growth of the CoJ in terms of waste management can be mitigated with the CE; the repurposing of waste, the reusing of waste or the recycling of waste by providing old waste with a new secondary life consisting of various forms of waste management (technologies, systems or methods promoting healthy waste management). Waste collected on landfill sites remains a hazard to the environment and the citizens of Johannesburg. Waste uncollected or unused accumulates requiring more space, more energy, and more resources. CE may be costly in the beginning but in the long-term, is highly effective and a worthy investment to make. Complicated techniques are not necessary for the CE to become a success in a country. This strategy is adapted to each country's capabilities, standards, and resources like that of the city of Oslo who only landfills 3% of its waste and has aimed for zero waste on landfill sites by 2030.

Originating from Guatemala, an eco-brick is a building block made up of a PET (Polyethylene Terephthalate) plastic bottle that is packed tightly with plastic waste. Filler material that can be used to make an eco-brick include paper, cardboard, tetra pack, metal, etc. It is a low-cost construction material and an effective method of plastic waste management [1]. Eco-bricks are made from 500 mL plastic bottles and have the potential to save about 200 g of waste and as such helps divert waste from landfills. A waste management method such as this is in-line with Pikitup's waste prevention strategy–reusing, recycling and recovery activities and net-zero waste plan by 2030.

In the year 2019, the first trial of the eco asphalt road was successfully trialed and implemented in Kwa-Zulu Natal. The trial included a paving mix that utilised a binder called HDPE (High-Density Polyethylene) to incorporate a portion of locally sourced recycled plastic waste. It was proven that the use of the binding agent in

the asphalt mixed increased the properties of the plastic in the asphalt mix, better enhancing the capabilities of the paving mixture (Shisalanga Construction 2019). Such initiatives, requires radical innovations and disruptive changes.

The circular economy is an innovative approach to resolving waste problems in the city by reducing natural resource exploitation, greenhouse gas emissions through optimum agricultural protection. For the circular economy to be as successful as EU countries, a waste hierarchy needs to be implemented in South Africa's current legislation laws for waste management to reduce waste production effectively. A country that wishes to adopt the CE successfully needs to [15]:

1. Develop a communal culture to environmental issues: such as a hierarchy on waste management as well as stating the importance of sustainable waste management and promoting public health,
2. Establish financial support or funding from the private and public sectors,
3. Governmental cooperation,
4. Ensure that adequate information on the CE is readily available,
5. Establish a demand and supply: this will help in developing the CE, acquiring of services to assist in the production of the CE and finding a need for secondary reused materials produced from the CE concept,
6. Protect the environment in terms or agriculture or non-renewable resources; and
7. Improve the quality of the developing products (Govindan and Hasanagic 2015).

5 Conclusion

The CE principles include the 3Rs (reduce, reuse, and recycle), but have been extended to include the 6Rs (reuse, recycle, redesign, remanufacture, reduce, and recover). Collaborative governance at national, municipal, and public sector levels on legal frameworks to the introduction of a new waste management strategy in RSA must be adopted to deal with financial, technical, and social obstacles and be steered to direct the cities' significant resources of physical, human, natural and intellectual capital towards the objective of a CE. This concept views waste as a sustainable resource. It has proven beneficial in European countries; hence the proposal to benchmark CoJ's waste solution with these different EU countries. Incorporating insight from a wide range of disciplines and accounting for externalities that can influence CE is a synergistic approach.

The drive to create a net-zero waste environment is heightened due to the lack of landfill space which the city no longer has. JHB has the opportunity to make advances in exploring potentials for and benefit from new CE initiatives. Adopting analyzed solutions for the CE transition entails good interrelations, however, education and training to raise awareness about the CE and to promote CE solutions will enable the city's approach to facilitate this transition and help overcome existing challenges.

The built environment is always changing. There is always room for innovative, positive, and sustainable methods for waste management to evolve or develop. Within the CE, a construction material such as eco-bricking was made, by re-using waste.

Eco-bricking will aid in addressing housing challenges in metrsopolitan cities such as Johannesburg where there is an influx of residents migrating for better living and working conditions. This construction material is durable, strong and complies with building standards. Hence, the CE can potentially prove beneficial for the built environment as a whole and not limited to only building management.

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