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Multi-criteria analysis for sustainable decision making: Opportunities for waste and recycling SMMEs (including cooperatives) in KwaZulu-Natal

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Abstract

This paper reports on a study for the KwaZulu-Natal (KZN) Department of Economic Development, Tourism and Environmental Affairs (EDTEA) by the Council for Scientific and Industrial Research (CSIR) to identify and maximize opportunities in the waste and recycling sector for "Small, Micro and Medium Enterprises (SMMEs) owned by women, youth, the disabled and previously disadvantaged" in the province. Opportunities from various waste streams as resource potential for SMMEs and cooperatives are presented, this is part of a KZN NCPC Industrial Symbiosis Programme in South Africa. The overall aim of the research project was to identify opportunities for SMMEs and cooperatives in KZN to exploit under exploited waste streams. This paper presents the findings for the first objective of the project namely, identifying waste streams that could provide income generating opportunities for SMMEs. This paper outlines the approach and methodology taken to prioritise a single waste stream that could provide income generating opportunities for SMMEs (including cooperatives) in the province. A multi-criteria approach was followed whereby waste streams were assessed based on various criteria: economic value; the amount and distribution of waste in the province; the type of waste streams; the availability and ease of roll out of technology options; ease of surmounting barriers to entry; market types and market availability; alignment and contribution to improving the sustainable development goals; opportunities for symbiotic relationships or collaborations. After assessing the qualitative and quantitative considerations, organic waste opportunities were determined to be the most ubiquitous and promising (with low barrier technology options for implementation) followed by bottom ash, as well as construction and demolition waste in the KZN province. These waste streams remain relatively unexploited. Composting is the recommended technology to treat the organic waste fraction due to the relatively small up-front investment required for set up, scalability, and relatively low skill requirements. In certain circumstances simple off the shelf anaerobic digestion technologies for other organic fractions could also be used. A top-down approach to SMME development is not advisable, therefore an important recommendation is that SMMEs (in particular cooperatives) which are already experienced and/or have a proven track record in composting should be considered for implementation.

Keywords: Composting, Cooperative, KwaZulu-Natal, Multi-Criteria Analysis, Organic Waste, SAWIC, SMME, Social Symbiosis, Sustainable Development Goals.

1 Introduction

Background

The CSIR) was tasked with identifying opportunities in the waste and recycling sector for '*(SMMEs) owned by women, youth, the disabled and previously disadvantaged* individuals' in the KwaZulu-Natal (KZN) province. The prioritised waste streams needed to be ubiquitous (i.e., known to be available in every municipality of the KZN province) and be relatively underexploited. These were the overall aims of the project initiated through the KZN Department of Economic Development, Tourism and Environmental Affairs (EDTEA) and overseen internally in the CSIR by the National Cleaner Production Centre (NCPC).

Decision making in waste management is a complex process because multiple stakeholders are often involved. This can sometimes include the different levels of government (like national, provincial, and local), different communities, and stakeholders in the private sector. This is further complicated by different waste collection routes, transfer station locations, treatment strategies, treatment plant locations, and sometimes a desire for energy recovery. Procedures that guide and support decision making for individuals or groups to achieve specific objectives to the very best discission possible given all the variables are known as decision support frameworks (Soltani *et al.*, 2015).

Solid waste management was further complicated during the Covid-19 pandemic. A nation-wide lock down was announced by the president on the 23rd of march 2020 (The Presidency, 2020). The lockdown mainly included restrictions on movement to curtail the spread of Covid-19. With the restrictions to movement came challenges in sourcing data for decision making purposes. Stakeholders were restricted to their homes and all except essential workers were allowed to travel to their normal places of work. This presented a further challenge to gathering information or data.

The overall project was designed around three phases namely: 1) the decision-making process to identifying a ubiquitous and priority waste stream (the subject of this paper), 2) identifying sources and quality of those waste sources and 3) the development of an implementation plan for small, medium, and micro sized enterprises (SMME) and co-operatives. This paper reports on the first phase of this project, namely the process followed to identify the priority waste streams. The selection of the priority waste streams was key to maximizing job opportunities for SMMEs. The client (EDTEA) was explicit in that the barriers to entry should be sufficiently low for the implementing agent to be able to roll out SMMEs in every municipality which were able to exploit a relatively under exploited waste stream. It was critical that existing waste streams or material flows which are already being utilised by other SMMEs, vulnerable groups, or other established entities be excluded, to avoid disrupting existing activities. The intention was to identify underutilised waste streams. It became apparent that the first task would be to identify waste streams in every municipality which ended up at landfill and were therefore under exploited. This is aside from the mainline recyclables (DEA, 2012) like paper, plastics, glass, and tins which tend to be cherry picked by the informal sector or recycling companies, including SMMEs, due to their market value.

Multicriteria Analysis

Multicriteria Analysis (MCA) is a useful tool in decision making (Alavi, Tavana and Mina, 2021; Ossei-Bremang and Kemausuor, 2021; Vlachokostas, Michailidou and Achillas, 2021). **Table** 3 outlines the criteria used for the Multicriteria Analysis (MCA) process. A description of how these criteria were utilised in this project including the prioritisation of waste streams are presented in the methods section below.

Type of Waste Streams

The waste types are classified as either being of a *general* or *hazardous* nature. Typically, the more complex the waste type, the more complex its management, including capital investment of resources required (technology, permits, licences, handling costs etc) to process these waste streams (DEA, 2011). SMMEs typically will undertake simple processing, which they are comfortable with and have an aptitude for. Although it is acknowledged that some innovative SMMEs are adept at exploiting complex and niche markets, this is generally not the case for all SMMEs (Scheinberg *et al.*, 2010). More complex tasks (like processing complex waste for instance) require complex skills, and larger budgets for capital infrastructure. This can be very expensive for an SMME or cooperative which may have less know-how in managing these complex waste streams. Thus, all waste streams which were classified as *hazardous* were excluded from consideration.

Impacts on Existing Livelihoods

This selection criterion considers the impact that undue competition from a newly formed waste SMME could have on already existing SMMEs or waste pickers. This would provide an unfair advantage to the new market entrants, especially if this was supported through new SMME's nurtured with public funding. The additional challenge is that the new entrant plus the existing SMMEs or waste pickers would be inadvertently competing for the same waste streams. It is well documented by other authors that in some cases the formation of a new group of market entrants can displace existing players (especially existing SMMEs and waste pickers) from earning their livelihoods (Gugssa, 2012; Chikarname, 2014; Lekhanya, 2016).

Different grades of plastic waste (see "General: Plastic: Polypropylene" in Table 3) are known to be collected by the informal sector. This forms a significant part of their livelihood (FAO, 2021; Laxmi Haigh et al., 2021). It is also known that recovery of plastics does take place at landfills with poor access control in the KZN province. It is nevertheless acknowledged that this end-of-pipe solution is not a suitable scenario. To avoid competing with these informal waste pickers livelihood, which is often linked with small buy back centre SMME, it was decided to exclude all plastic waste from this project's consideration. Similarly, "General: Construction and demolition waste" is also known to be widely distributed in the province (but underutilised). However, municipalities are often short of cover material for proper management at their landfills. Construction and demolition waste can be a suitable substitute to sand and gravel for covering the existing working face of an active landfill (Nell et al., 2022).

"General: Municipal waste" is well distributed in the province and it is known that there are also large volumes of this waste stream. This is disposed of to landfill sites co-mingled and contaminated with different other wastes and recyclables, separation at source typically being poorly implemented. This is also true of waste from the commercial sector (i.e. "General: Commercial and industrial waste") which is similar in character to municipal solid waste (DEA, 2012; Swanepoel et al., 2012; Mutezo, 2015). The recyclables from municipal and commercial and industrial waste are harvested by the informal sector or SMMEs at kerb sides and many landfill sites.

Table 1: Scoring criteria used

No	Criteria	Organic Waste	SCORE
1	Availability of Technology	High – Simple Tech options available	3
		Medium	2
		Low – Only complex Tech options	1
2	Barriers to Entry	No Known barriers	3
		Low barriers to entry	2
		High - Considered insurmountable barriers	1
3	Existing markets	National or international	1
		Regional	2
		Local	3
4	Alignment with SDGs	GOAL 1: No Poverty	1/17
		GOAL 2: Zero Hunger	1/17
		GOAL 3: Good Health and Well-being	
		GOAL 4: Quality Education	
		GOAL 5: Gender Equality	1/17
		GOAL 6: Clean Water and Sanitation	1/17
		GOAL 7: Affordable and Clean Energy	1/17
		GOAL 8: Decent Work and Economic Growth	1/17

		GOAL 9: Industry, Innovation, and Infrastructure	
		GOAL 10: Reduced Inequality	
		GOAL 11: Sustainable Cities and Communities	1/17
		GOAL 12: Responsible Consumption & Production	1/17
		GOAL 13: Climate Action	1/17
		GOAL 14: Life Below Water	1/17
		GOAL 15: Life on Land	1/17
		GOAL 16: Peace and Justice Strong Institutions	
		GOAL 17: Partnerships to achieve the Goal	1/17
		Opportunities exist	2
5	Industrial Symbiosis Opportunities?	No opportunities	1
		Impacts negatively on existing relationships	0

It was decided not to 'cannibalize' these valuable waste streams, even though it was likely that more cover material than the municipalities could utilize is likely available. Similarly due to the recovery of main line recyclables such as plastics, paper, and cardboard, these were excluded from the selection process and are not considered further. The project adopted a social symbiotic (Akrivou *et al.*, 2022) approach was taken in which the livelihoods of other stakeholders was considered (i.e., pickers and SMME which may be dependent on plastics for their survival as well as the municipalities) through this project.

Availability and Ease of Roll Out of Technology Options

The type of technology is an another criterion to consider, especially if expertise of how to operate equipment (or technology) is not already inherent or present within the SMMEs (Kirchherr *et al.*, 2018). The selection of waste streams with a preference for general rather than hazardous waste categories will to some extent mitigate this, as general waste streams typically require less advanced technology to process. Learning complex new skills requires expensive investments (in time and costs) to deliver quality goods to market. In essence, the technology required to add value to the waste streams needs to be simple enough to enable uptake by low skill or inexperienced SMMEs and to deliver the required outputs.

Barriers to Entry

For some beneficiation opportunities, there may be significant barriers to entry which need to be overcome to enable development and commercialisation. In cases where there are significant barriers to entry, it may be difficult for new SMME entrants. Two main aspects considered under this criterion are Legislation and Financial barriers. From a legislative perspective, the need for environmental impact assessments, registration (or permitting) of a waste facility, or the associated compliance requirements could apply especially if the volumes of waste processed are above cut off thresholds. For the financial barriers capital outlays required for licencing, availability of a clean feedstock or processing costs could be significant. The waste stream to be selected or prioritised should have minimal barriers to entry for new SMME entrants.

Potential Market Types

Availability of markets is critical for the establishment of a successful and flourishing SMME. Transportation is a significant cost component (up to or even above 50%) of waste management activities and is therefore a critical factor in the success or failure of an SMME (Olawale and Garwe, 2010; Business Environment Specialists, 2014). The transport costs must be balanced or considered with the relative value of the material being transported. Therefore, it makes sense that processing of waste should ideally be done as close as possible to the source of generation. The final SMME processed waste product is likely to be of higher value compared to unprocessed waste, the end market should also ideally be in close proximity to bring down costs. Distance to potential markets will be used to assess the waste value adding opportunities for SMMEs. If the waste is produced far away (i.e., another province, national, or international), this could potentially be detrimental to the utilisation of the waste stream by the SMME. For instance, in order to reduce transport costs the producer of the waste can also be the market for the product(s) or by products (electricity in the form of gas etc. can be utilised in-house). This creates a "win-win" scenario that reduces transport and other transaction costs. This can also be extended to incorporate other institutions or organisations operating within a local area.

Alignment to Sustainable Development Goals (SDGs)

Sustainability objectives in the form of the SDGs (i.e., environmental, social, and economic impacts) were considered and evaluated based on the team's collective experience. The final choice of waste stream should be evaluated based on how the project will contribute towards supporting the SDGs (RSA, 2019b).

Figure 1: The Sustainable Development Goals[2]

[2] *https://www.un.org/development/desa/disabilities/envision2030.html*

Potential for Symbiotic Relationships

The opportunity to leverage symbiotic relationships was considered. Opportunities to develop mutually beneficial relationships may include for example a structured Broad-Based Black Economic Empowerment program (RSA, 2013). This could be between a large private company or a public sector institution (i.e., schools or hospitals) which produces a waste stream and an SMME. The waste producer can offset its disposal costs (including its transportation and landfill gate fees) by diverting this waste to a local SMME. The SMME could benefit from mentorship, access to a 'free' or subsidised source of raw material to use in its processes. This symbiosis between a manufacturer or industry and an SMME could have multiple benefits and widespread impact if the waste stream in question is easily available in the province and well distributed.

A methodology and approach to the research study are presented in section 2 of this paper. This includes some context in utilising a multicriteria approach. This is followed by some results and a discussion in section 3. Section 4 outlines the main conclusions of this study.

2 Methodology And Approach

Approach followed

A mixed methods data collection approach was followed involving both quantitative and qualitative techniques. Firstly, quantitative data was sourced from SAWIS for an understanding of the types and distribution of different waste streams finding their way to landfill sites in the KZN province as reported by the different municipalities. A report of wastes disposed per municipality was generated for the year 2019, this was summarized per waste type. It was found that only 18 of the 43 municipalities reported waste disposal data to SAWIS in 2019. Secondly, several criteria were considered of importance to ensure that the waste type prioritized was able to provide opportunities for '(SMMEs) owned by women, youth, the disabled and previously disadvantaged'. The criteria were based on the amount and distribution of waste in the province; the type of waste streams (including if it was general versus hazardous waste). Lastly, a scoring matrix was applied based on the availability and ease of roll out of technology options; ease of surmounting barriers to entry (including legislative, compliance and financial barriers); potential market types and market availability; alignment and contribution to the SDGs; opportunities for symbiotic relationships and impacts on existing livelihoods.

SAWIS Data Analysis

Despite 2019 being chosen as the year for analysis, the project team decided that it would be prudent to also examine data for at least 3 years (i.e., for 2019, 2018 and 2017) in case some waste types were missing, which might be the case if just one year was considered.

Data for KZN (for 2019, 2018, and 2017) was then downloaded from SAWIS in the year of the project, 2019[3], all analysis was done in MS Excel. **Table 1** below provides a summary of these waste streams from the SAWIS database for 2019, 2018 and 2017. The facilities represent the entities where the waste was disposed i.e., the landfill sites in each municipality. Most municipalities small municipalities typically report disposal at a single facility except for the eThekwini Metro (i.e., there were five facilities disposing "General: Municipal waste"), Newcastle (KZN252) had two facilities reporting "Hazardous: Liquid and sludge inorganic waste" and uMhlathuze (KZN282) had two facilities reporting "General: Construction and demolition waste" for 2019. Only 18 of the 43 local municipalities and one metropolitan municipality in KZN reported data to SAWIS for the three years under investigation.

Table 2: Waste types based on facilities & mass reported (Tons/Annum) per year (SAWIS)

Waste Types	2019		2018		2017	
	Facilities	Tons	Facilities	Tons	Facilities	Tons
General: Municipal waste	19	641,047	17	773,161	16	695,911
General: Construction and demolition waste	11	441,503	9	674,425	9	668,487
General: Commercial and industrial waste	8	206,701	8	278,517	8	288,379
General: Metals: Ferrous metal	2	1,674,032	2	7,560	2	9,151
General: Other	8	109,234	5	185,577	7	171,836
General: Organic waste	5	196,563	3	298,047	3	318,027
Hazardous: Liquid and sludge inorganic waste	5	131,796	4	124,611	5	131,761
General: Organic waste: Garden waste	10	47,992	8	52,705	8	61,555
General: Slag: Ferrous metal slag	2	108,781	2	232,391	2	167,832
Hazardous: Solid inorganic waste	3	37,732	3	57,338	2	124,691
General: Bottom ash	5	45,537	10	22,769	4	21,975
General: Slag: Non-ferrous metal slag	1	194,846	1	100,593	1	215,996
Hazardous: Miscellaneous	3	13,723	3	38,902	2	75,461
Hazardous: Bottom ash	2	22,260	2	45,846	3	35,116
General: Metals: Non-ferrous metal	2	167,860	1	959	1	686
Hazardous: Liquid and sludge organic waste	3	9,627	2	24,198	2	19,943
Hazardous: Fly ash and dust from miscellaneous filter sources: Fly ash	2	10,661	2	31,120	1	9,786
Hazardous: Solid organic waste	3	2,661	3	3,902	2	16,626
Hazardous: Mineral waste: Refractory waste	1	76	2	12,243	2	16,262
Hazardous: Solids containing halogens and/or sulphur	1	5,230	1	12,793	2	5,454
Hazardous: Spent pot lining (organic)	1	3,650	1	10,099	1	9,399
Hazardous: Waste oils: Waste oil	2	3,896	1	2,665	2	4,045
General: Organic waste: Food waste	5	204	3	113	3	4,108
General: Slag: Other	1	12,298	1	9,139	0	0
General: Sewage sludge	2	338	2	4,921	3	499
Hazardous: Lead batteries	1	6,371	1	13	1	11
General: Plastic: Polypropylene	0	0	0	0	1	14,500
Hazardous: Mineral waste: Foundry sand	0	0	1	360	1	6,547
General: Organic waste: Wood waste	1	2	1	2,304	1	1,588
General: Mineral waste: Refractory waste	1	9,754	0	0	0	0
Hazardous: Asbestos containing waste	2	599	2	57	2	235
General: Mineral waste: Foundry sand	2	1,068	1	319	0	0
Hazardous: Health care risk waste: Infectious waste and sharps	1	764	0	0	1	777
Hazardous: Mercury containing waste: Solid waste containing mercury	0	0	1	0	1	1,285
General: Tyres	1	24	2	36	3	339
Hazardous: Health care risk waste: Pathological waste	1	1,631	0	0	0	0
Hazardous: Bituminous waste	1	13	1	32	2	279

[3] *It is important to note that the database is sometimes revised as more accurate data is incorporated for some of the previous years or indeed even the current period.*

Waste Types	2019		2018		2017	
	Facilities	Tons	Facilities	Tons	Facilities	Tons
Hazardous: Solvents without halogens and sulphur	0	0	1	19	2	216
Hazardous: WEEE: Entertainment and consumer electronics and toys, leisure, sports and recreational equipment and automatic issuing machines	0	0	1	0	1	213
Hazardous: Liquids and sludges containing halogens and/or sulphur	1	11	1	12	1	84
General: Plastic	3	69	0	0	0	0
Hazardous: Health care risk waste: Chemical waste	1	87	0	0	1	1
General: Brine	0	0	2	83	0	0
General: Fly ash and dust from miscellaneous filter sources	1	124	0	0	0	0
Hazardous: Sewage sludge	0	0	0	0	1	91
General: Plastic: Other	1	50	0	0	0	0
Hazardous: POP waste: Other POP-containing waste	0	0	0	0	1	44
Hazardous: Mineral waste: Other	0	0	0	0	1	33
General: Metals	3	8	0	0	0	0
General: Paper	2	10	0	0	0	0
General: WEEE: Mixed WEEE	1	14	0	0	0	0
General: Glass	1	12	0	0	0	0
Hazardous: WEEE: Office, information, and communication equipment	1	0	1	2	1	0
Hazardous: WEEE: Lighting equipment	0	0	0	0	1	4
Hazardous: Mixed batteries	0	0	1	0	1	1
General: WEEE: Small household appliances	1	2	0	0	0	0
Hazardous: Mercury containing waste: Liquid waste containing mercury	0	0	0	0	1	1
General: Plastic: Polyethylene terephthalate	0	0	0	0	1	1
General: Plastic: Polyvinylchloride	1	1	0	0	0	0
General: WEEE: Lighting equipment	1	1	0	0	0	0
Hazardous: Manganese dioxide and alkali batteries	0	0	0	0	1	0
TOTAL	**136.0**	**4,108,860**	**113.0**	**3,007,830**	**118.0**	**3,099,232**

The relative tonnages provide some context in terms of the annual masses reported. While this approach assumes that all waste being disposed of to landfills is reported this is known not to be the case (DEA, 2018). Also, not all of the KZN landfills are licensed (Gerdman, 2018; Packaging SA, 2018), nor do all of them have functional weigh bridges, thus compromising the accuracy of the reporting into SAWIS. This adds an element of uncertainty to the SAWIS data which has also been previously reported by other authors (Chagunda, 2019; Williams-Wynn and Naidoo, 2020). Nevertheless, the SAWIS database provides some useful insights into the type of wastes finding their way to landfill which can be aggregated at a provincial or national level. The above uncertainties and data gaps were mitigated based on the project teams experience of conducting seasonal waste characterisation studies within several other metros, small KZN municipalities and having access to waste characterisation data from other studies conducted in South Africa.

The data analysis is presented in Table 2 as follows: The average number of facilities reporting was calculated to account for the year-on-year variation (column A). Similarly, the average tonnages reported over the three-year period was calculated and reported in column B). It is therefore concluded that an average of seventeen (17) facilities were disposing an average of 703,373 tones/annum of "General: Municipal waste" over a three-year period (from the 2019, 2018 and 2017). From these two datasets (A and B from the table below) an index of priority (by multiplying column A x column B for each waste type) could be calculated.

Table 3: Calculated average (2019, 2018 & 2017) facilities reporting waste types & Tons/Annum

	Waste Type	A = Average Facilities[4]	B = Average Tons/Annum[5]	INDEX = A x B
1	General: Municipal waste	17.3	703,372.5	12,191,790.0
2	General: Construction and demolition waste	9.7	594,804.8	5,749,779.7
3	General: Commercial and industrial waste	8.0	257,865.6	2,062,925.1
4	General: Metals: Ferrous metal	2.0	563,581.0	1,127,162.0
5	General: Other	6.7	155,549.0	1,036,993.3
6	General: Organic waste	3.7	270,879.2	993,223.7
7	Hazardous: Liquid and sludge inorganic waste	4.7	129,389.4	603,817.4
8	General: Organic waste: Garden waste	8.7	54,083.8	468,726.3
9	General: Slag: Ferrous metal slag	2.0	169,668.2	339,336.5
10	Hazardous: Solid inorganic waste	2.7	73,253.5	195,342.8
11	General: Bottom ash	6.3	30,093.5	190,592.4
12	General: Slag: Non-ferrous metal slag	1.0	170,478.2	170,478.2
13	Hazardous: Miscellaneous	2.7	42,695.1	113,853.6
14	Hazardous: Bottom ash	2.3	34,407.6	80,284.4
15	General: Metals: Non-ferrous metal	1.3	56,501.8	75,335.7
16	Hazardous: Liquid and sludge organic waste	2.3	17,922.8	41,819.9
17	Hazardous: Fly ash and dust from miscellaneous filter sources: Fly ash	1.7	17,188.7	28,647.8
18	Hazardous: Solid organic waste	2.7	7,729.5	20,611.9
19	Hazardous: Mineral waste: Refractory waste	1.7	9,527.0	15,878.3
20	Hazardous: Solids containing halogens and/or sulphur	1.3	7,825.5	10,434.0
21	Hazardous: Spent pot lining (organic)	1.0	7,716.2	7,716.2
22	Hazardous: Waste oils: Waste oil	1.7	3,535.7	5,892.8
23	General: Organic waste: Food waste	3.7	1,474.9	5,407.8
24	General: Slag: Other	0.7	7,145.6	4,763.7
25	General: Sewage sludge	2.3	1,919.3	4,478.3
26	Hazardous: Lead batteries	1.0	2,131.5	2,131.5
27	General: Plastic: Polypropylene	0.3	4,833.3	1,611.1
28	Hazardous: Mineral waste: Foundry sand	0.7	2,302.2	1,534.8
29	General: Organic waste: Wood waste	1.0	1,297.8	1,297.8
30	General: Mineral waste: Refractory waste	0.3	3,251.5	1,083.8
31	Hazardous: Asbestos containing waste	2.0	296.8	593.5
32	General: Mineral waste: Foundry sand	1.0	462.3	462.3
33	Hazardous: Health care risk waste: Infectious waste and sharps	0.7	513.7	342.4
34	Hazardous: Mercury containing waste: Solid waste containing mercury	0.7	428.4	285.6
35	General: Tyres	2.0	133.0	266.1
36	Hazardous: Health care risk waste: Pathological waste	0.3	543.7	181.2
37	Hazardous: Bituminous waste	1.3	108.1	144.1
38	Hazardous: Solvents without halogens and sulphur	1.0	78.3	78.3
39	Hazardous: WEEE: Entertainment and consumer electronics and toys, leisure, sports and recreational equipment and automatic issuing machines	0.7	70.8	47.2
40	Hazardous: Liquids and sludges containing halogens and/or sulphur	1.0	35.7	35.7
41	General: Plastic	1.0	23.1	23.1
42	Hazardous: Health care risk waste: Chemical waste	0.7	29.2	19.5
43	General: Brine	0.7	27.7	18.4
44	General: Fly ash and dust from miscellaneous filter sources	0.3	41.2	13.7
45	Hazardous: Sewage sludge	0.3	30.2	10.1
46	General: Plastic: Other	0.3	16.6	5.5
47	Hazardous: POP waste: Other POP-containing waste	0.3	14.7	4.9
48	Hazardous: Mineral waste: Other	0.3	11.0	3.7
49	General: Metals	1.0	2.7	2.7
50	General: Paper	0.7	3.3	2.2
51	General: WEEE: Mixed WEEE	0.3	4.7	1.6

[4] *For 2019, 2018 and 2017.*

[5] *For 2019, 2018 and 2017.*

52	General: Glass	0.3	3.9	1.3
53	Hazardous: WEEE: Office, information, and communication equipment	1.0	0.6	0.6
54	Hazardous: WEEE: Lighting equipment	0.3	1.4	0.5
55	Hazardous: Mixed batteries	0.7	0.3	0.2
56	General: WEEE: Small household appliances	0.3	0.5	0.2
57	Hazardous: Mercury containing waste: Liquid waste containing mercury	0.3	0.4	0.1
58	General: Plastic: Polyethylene terephthalate	0.3	0.3	0.1
59	General: Plastic: Polyvinylchloride	0.3	0.3	0.1
60	General: WEEE: Lighting equipment	0.3	0.2	0.1
61	Hazardous: Manganese dioxide and alkali batteries	0.3	0.1	0.0
	TOTAL	**122.3**	**3,405,307.4**	

This approach is somewhat similar to the process followed by Wekisa & Majale (2020) for their aggregated quality of life index, except for the variables used, and no weighting was applied in this case (i.e. no waste streams were favoured above another by using a weighting in this case). It is logical that if a waste stream is well distributed (i.e., found in many municipalities) then the number of Facilities reporting it will be high. Thus, multiplying this high distribution, by a high annual tonnage will produce a large number compared to if both variables were low. This will be done for all the criteria specified previously.

Multicriteria Analysis and scoring

A discussion on MCA including the aspects considered for this project was presented previously. Table 3 presents the results for the calculated index based on the distribution and tonnages of different waste types. This was further assessed based on criteria to ensure that the prioritised shortlist indeed meets the requirements of the study, namely, a ubiquitous waste stream, relatively simple to exploit and available off the shelf technology to implement. This is initially based on a calculated index, and then assessed on a scoring system. This approach to scoring for the analysis is presented below:

Amount and Distribution

The highest index (A x B) waste streams in Table 3 would appear to be good candidates for shortlisting. However, it should be noted that a number of these are based on very low distribution waste streams (i.e. tonnages for the fractions of waste being disposed to landfill is very high which leads to a skewing of the index). For instance, "General: Metals: Ferrous metal", "General: Slag: Ferrous metal slag" were reported by only two facilities in KZN but the annual waste tonnages reported was high; "General: Slag: Non-ferrous metal slag" (reported by one facilities) and "General: Metals: Non-ferrous metal" (reported by one facility only). Considering that the SAWIS database is based on the reporting of 18 municipalities, therefore the team took a view that any waste stream with less than 50% coverage (or a nine in column A) would have a questionable distribution and was therefore excluded from Table 3, unless the team knew from prior experience that the opposite was true.

Type of Waste Streams

More complex tasks require complex skills, and large budgets for capital infrastructure. This can be very expensive for an SMME or cooperative. Thus, all waste streams which were classified as *hazardous* were excluded from the Table 3.

Impacts on Existing Livelihoods

Impacts on existing livelihoods was an important consideration for the team. Plastics, "General: Municipal waste" (which also contain recyclables) and "General: Construction and demolition waste", were excluded from consideration as discussed previously. The remaining criteria were scored according to Table 1 also discussed previously. This is based on the project team's experience from similar projects conducted in the past and therefore it is acknowledged that there may be some subjectivity in the process.

Availability and Ease of Roll Out of Technology Options

Waste streams where simple technology options are available were favoured (and thus scored 3), higher than a waste type where technology options were complex or expensive (i.e. scored 1).

Barriers to Entry

This criterion was scored based on either no known barriers (score 3), low barriers (score 2) or the potential for insurmountable barriers to entry (score 1).

Potential Market Types

This criterion was scored based on either known international markets (score 1), regional markets (score 2) or local markets (score 3).

Alignment to Sustainable Development Goals (SDGs)

If the beneficiation of the waste stream could contribute towards the realization of an SDG, this was scored positively. The more SDG's it could contribute to the higher the score. Each SDG was scored as a single point; the total points were then divided by 17 (17 SDGs). Therefore, if the waste stream could lend itself to a goal, it received a score of 1/17 for each goal.

Potential for Symbiotic Relationships

Scoring was assigned based on the likelihood of opportunities for a symbiotic relationship (score 2), no likely opportunities (score 1) or the possibility for negative impacts (score 0). The next section outlines a discussion on the shortlisted waste streams.

Short Listed Waste Streams

Table 3 revealed several waste streams which were well distributed throughout the province. However, a number of these were excluded due to the likelihood of having a poor spatial distribution as well as already being utilised by other stakeholders for their livelihoods. After assessing the remaining waste streams based on multiple criteria in section 2.3, a short list of possible waste streams remained. Of the eight items on this list, six are of organic origin. This includes the waste stream labelled as "General: Other" which is reported as including "biomass waste from industry" (DEA, 2012). Note that initially "General: Organic waste: Food waste", "General: Sewage sludge", and "General: Organic waste: Wood waste" were excluded from consideration, however it is known that these waste streams are indeed well distributed in the province. It is therefore likely that this is a deficiency of the SAWIS database. Therefore, the following items are included in the final listing below.

Table 4: Summary of shortlisted waste streams

	Waste Type	A = Average Facilities[6]	B = Average Tons/Annum[7]	INDEX = A x B
1	General: Other[8]	6.7		1,036,993.3
2	General: Organic waste	3.7	270,879.2	993,223.7
3	General: Organic waste: Garden waste	8.7	54,083.8	468,726.3
4	General: Bottom ash	6.3	30,093.5	190,592.4
5	General: Organic waste: Food waste	3.7	1,474.9	5,407.8
6	General: Sewage sludge	2.3	1,919.3	4,478.3
7	General: Organic waste: Wood waste	1.0	1,297.8	1,297.8

The above waste streams (including the 6 aggregated organic wastes) were subjected to one final set of analysis. These items were scored using the system described in section 2.3 under the different criteria. The results are presented below in the results section.

3 Results and Discussion

In terms of achieving the SDGs organic waste streams achieved the higher score. Both bottom ash and organic waste fractions could contribute to job creation opportunities (goal 1) and hence the alleviation of poverty, sustainable cities and communities (goal 11), responsible consumption and production (goal 12), climate action (goal 13), better life above land (goal 16) and opportunities for symbiotic relationships (goal 17). Organic waste has the potential to contribute to agricultural applications hence contributing to goal 2 and goal 3 (Nottingham, 2012; Pretorius, 2014; Haburukundo, 2019). Both waste fractions could contribute to decent work (goal 8) and be beneficiated by

[6] For 2019, 2018 and 2017.

[7] For 2019, 2018 and 2017.

[8] This is biomass waste from industry.

both men and women (goal 5). Anaerobic processes utilising organic wastes in combination with sewage sludge could contribute to better management of water sources (goal 6 & goal 14) which can also assist with local energy sources (goal 7) from the anaerobic processes (Tumwesige, Fulford and Davidson, 2014; Cândido *et al.*, 2022; López-Dávila *et al.*, 2022) .

Table 5 presents the final scoring of the two main waste streams. A large proportion of these are organic waste fractions and are therefore represented under the broad category of organic waste streams. Based on the scoring, organic wastes were prioritised for beneficiation by SMMEs in the next stages of the project (score of 12,824 versus Bottom ash with a score of 11,529).

Considering the different types of organic waste, several simple off the shelf technology options exist for the different organic fractions. Some of these include composting of the woody organic waste fractions (Couth and Trois, 2012) and relatively simple anaerobic digestion of food waste fractions (Kumar and Bharti, 2012; DEA, 2015). A number of options to utilise bottom ash depend on the processing, the input waste quality and existing regulations – this applies to bottom ash use in block manufacture, soil amelioration, as a concrete extender, for road construction, or fill material (Hallowes and Munnik, 2017). Recently Eskom applied for approval to the DFFE to exclude bottom ash from the definition of waste. Although there are no coal fired power stations in KZN it could be argued that a similar process could be undertaken for other large producers of bottom ash (RSA, 2019a, 2020; Eskom, 2021; Godfrey, 2021). Because of this potential national legal barrier for approved sources of bottom ash (RSA, 2020) this opportunity was scored lower than organic waste fractions which have a relatively less rigorous and onerous approval process and are dependent on local site specific conditions. Both bottom ash and the different organic waste fractions could find local market applications and were scored the maximum of three (3) for this criterion. This is significant because transport costs could render many waste beneficiation projects unviable (Coelho and De Brito, 2013).

Table 5: Final Scoring

No	**Criteria**	**Finding**	**Potential Score**	**Bottom Ash**	**Organic Waste**
1	Availability of Technology	High – Simple Technology options available	3	3,00	3,00
		Medium	2		
		Low – Only complex Technology options	1		
2	Barriers to Entry	No Known barriers	3		3,00
		Low barriers to entry	2	2,00	
		High - Considered insurmountable barriers	1		
3	Existing markets	National or international	1		
		Regional	2		

		Local	3	3,00	3,00
4	Alignment with SDGs	GOAL 1: No Poverty (1/17)	0,06	0,06	0,06
		GOAL 2: Zero Hunger (1/17)	0,06		0,06
		GOAL 3: Good Health and Well-being (1/17)	0,06		0,06
		GOAL 4: Quality Education (1/17)	0,06		
		GOAL 5: Gender Equality (1/17)	0,06	0,06	0,06
		GOAL 6: Clean Water & Sanitation (1/17)	0,06		0,06
		GOAL 7: Affordable & Clean Energy (1/17)	0,06		0,06
		GOAL 8: Decent Work and Economic Growth (1/17)	0,06	0,06	0,06
		GOAL 9: Industry, Innovation & Infrastructure (1/17)	0,06		0,06
		GOAL 10: Reduced Inequality (1/17)	0,06		
		GOAL 11: Sustainable Cities & Communities (1/17)	0,06	0,06	0,06
		GOAL 12: Responsible Consumption & Production (1/17)	0,06	0,06	0,06
		GOAL 13: Climate Action (1/17)	0,06	0,06	0,06
		GOAL 14: Life Below Water (1/17)	0,06	0,06	0,06
		GOAL 15: Life on Land (1/17)	0,06	0,06	0,06
		GOAL 16: Peace & Justice Strong Institutions (1/17)	0,06		
		GOAL 17: Partnerships to achieve the Goal (1/17)	0,06	0,06	0,06
5	Opportunities for symbiotic relationships	Opportunities exist	3	3,00	3,00
	(BBBEE in Industrial Symbiosis)	No opportunities	2		
	Impacts negatively on existing livelihoods		1		
			TOTAL	**11,529**	**12,824**

4 Conclusion and Recomendations

This study found that there are opportunities for SMME's and cooperatives in KZN to utilize several relatively unexploited organic waste streams, including biomass, food, wastewater sludge and garden waste. These waste streams were found to be relatively widely distributed and underutilized throughout KZN. Several sources for these organic wastes include institutions such as fresh produce markets, commercial agricultural sources, schools, hospitals, and prisons. Off the shelf, relatively simple treatment technologies can be utilized for these under-exploited wastes. A number of recommendations are made below:

The study noted the general finding from other authors which indicated the poor separation at source of co-mingled waste streams, which presents a challenge to any beneficiation project. It is recommended that separation at source be implemented to improve the quality of recyclables as well as increasing quantities recovered.

There is also a need for improved reporting on the SAWIS database (by more private sector entities and municipalities). In terms of both the coverage and quality of information reported by waste type, this could be improved to assist discission making.

The appropriate organic waste treatment method is dependent on the specific organic waste fraction. For instance, composting can be utilised for woody and heavily lignified garden wastes, while anaerobic digestion could be utilised for food waste fractions and less lignified organic waste fractions. Both technologies are available for a relatively small up-front investment required for set up, are easily scalable, and have relatively low skills requirements, ideally suited for an SMME. Different composting technologies are also available which provides opportunities for small-scale, large scale, in-vessel, and open windrow type operations.

A top-down approach to SMME (or cooperative) development is not advisable due to the likelihood of failure. Therefore, SMMEs (and cooperatives) which are already established and have a proven track record in the waste management space should be prioritised for implementation. The first prize is if such enterprises are already operating as either composters or possibly utilizing small scale anaerobic digestion.

Other waste streams that are known to be well distributed throughout KZN are bottom ash (although legislative barriers need to be overcome), as well as construction and demolition waste, although some of this is routinely being used for cover material on landfill sites. Other opportunities including glass waste (from MSW sources) with low technology processing could also be explored, however this excludes bottle to bottle reuse because there is no bottle plant in KZN, and the transport costs are likely to make any such enterprise uneconomical. Other opportunities for re-use include the construction sector, where crushed glass could be utilized as a filler for cement for compacted earth bricks, or for sandblasting.

Uptake of the identified opportunities could be facilitated through funded feasibility studies which will provide the required information for SMMEs to make informed decisions on technology choices and preferred location of the identified feasible opportunities.

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opportunities within the waste sector. This project is therefore also aligned with identifying opportunities for SMMEs and cooperatives in KZN.

Conflict of Interest

The authors declare that there is no competing interest.

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