

IMPLEMENTING THE WASTE MANAGEMENT HIERARCHY: APPLYING THE SASCOST MODEL TO DETERMINE INDICATIVE COSTS OF SEPARATION AT SOURCE

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ABSTRACT

The SASCOST model is a tool for comparing the costs and benefits of alternative options for implementing a Separation at Source (S@S) recycling programme. S@S is a crucial step in implementing the waste management hierarchy. The model can be used by municipalities as a Decision Support Tool to identify the most cost-effective option for implementing S@S in different areas; based on the specific context of each area. In this paper, we apply the model to provide some indicative information on the unit costs of implementing S@S in a range of different municipal contexts, as well as the total cost of rolling out S@S nationwide. The results indicate that the cost of implementing S@S varies significantly depending on the type of collection system (post separation, truck and trailer, separate vehicle or 'rich bag'), and on the type of municipality. For example, based on hypothetical data, the additional cost of implementing a separate vehicle system ranges from R17 per household per month (Category A municipalities), to R60 per household per month (Category B4 municipalities); based purely on financial costs. Aggregating these costs to the national level, the results suggest that the costs of rolling out S@S nationwide would range from approximately R4 billion to R6.2 billion, depending on the type of collection system. However, there are also some benefits and savings associated with S@S, which should also be taken into account in decision making. In particular, when socio-economic and environmental impacts are included, there is a big swing toward all systems yielding significant net benefits.

KEYWORDS

Municipal solid waste, recycling, Separation at Source, kerbside collection, logistics, Materials Recovery Facility, Cost-Benefit Analysis, modelling.

INTRODUCTION

The National Environmental Management: Waste Act, 2008 (No. 59 of 2008) (Republic of South Africa, 2008) calls for increased diversion of waste away from landfill towards re-use, recycling and recovery. Nevertheless, South Africa generates an estimated 108 million tonnes of waste per annum (as at 2011), of which 98 million tonnes (or 90%) is disposed of to landfill. Countrywide, an estimated 20 million tonnes of municipal solid waste is generated per annum, of which about 25% consists of mainline recyclables (paper, plastics, glass, tins and tyres) (Department of Environmental Affairs (DEA) 2012). In 2014, an estimated 3.39 million tonnes of packaging was consumed in South Africa, of which only 52.6% was recycled (Packaging SA, 2015), with the remainder disposed of at landfills.

In response, government has set a target of 25% diversion of recyclables from landfill for re-use, recycling and recovery by 2016, as part of its National Waste Management Strategy (NWMS) (DEA, 2011). The NWMS also promotes “Separation at Source” (S@S) programmes; in which waste generators (households, businesses etc.) separate recyclables from non-recyclable waste, while the municipality must create an enabling environment for the collection of source-separated recyclables. A target was set for all metropolitan municipalities, secondary cities and large towns to have initiated such programmes by 2016. While there are no official statistics on the number of municipalities to have met this target, it is clear that there are many who haven’t. At the same time, there have been indications that the DEA intends to make it mandatory for municipalities to implement such programmes.

However, a separate collection system is likely to increase the overall costs of waste management. There is currently a knowledge gap in terms of how to best implement S@S, specifically in terms of how the separated recyclables should be collected (e.g. separate vehicles, multi-compartment vehicles, truck and trailer, or incorporating the informal sector). The different collection options have different financial, socio-economic and environmental implications (costs and benefits); including capital and operating costs, job creation, impacts on the livelihoods of informal collectors, and environmental impacts associated with transport, such as CO₂ emissions.

In turn, the costs and benefits of alternative systems will be influenced by a range of factors (e.g. waste types and quantities generated, collection and transport distances, etc.). As such, these costs and benefits are likely to differ between municipalities, and even between different suburbs within the same municipality, depending on the specific context (population, socio-economic profile, waste generation rates, waste composition, location, etc.).

As such, there is a need to provide municipalities (or their service providers) with decision support in assessing the costs and benefits of alternative systems for implementing S@S. In response, the CSIR has developed a spreadsheet-based mathematical model for assessing and comparing the costs and benefits of alternative collection systems for source separated waste, taking into account each municipality’s specific context. The SASCOST model can be used as a decision support tool by a municipality (or service provider) to identify the most cost-effective option for implementing S@S (i.e., the system with the lowest net cost), given its unique circumstances.

In addition, it has been proposed that the model can provide useful information on the total cost of rolling out S@S nationwide, and therefore to inform current policy discussions regarding potential legislation for mandatory implementation of S@S. In this paper, we apply the SASCOST model to provide some indicative information on the unit costs of implementing S@S in a range of different municipal contexts, as well as the total cost of rolling out S@S nationwide.

BRIEF OVERVIEW OF THE SASCOST MODEL

The SASCOST model is a spreadsheet-based model (although an online interface is currently being developed) in which users enter some basic input data, on the basis of which the model calculates the costs of different options for implementation of S@S. Specifically, the model assesses four different types of collection system:

1. “POST SEPARATION”: No separation at source; post-separation of recyclables at ‘dirty’ MRF (Materials Recovery Facility); residual waste transported to landfill.

2. "TRUCK & TRAILER": S@S; kerbside collection of recyclables in trailer hitched to back of normal waste collection vehicle (where possible); recyclables sorted and baled at 'clean' MRF; residual waste transported to landfill.
3. "SEPARATE VEHICLE": S@S; kerbside collection in separate vehicles (by municipality, contractor/private sector or cooperative); recyclables sorted and baled at clean MRF; residual waste transported to landfill.
4. "RICH BAG": Households place recyclables in separate bag at top of bin; collected by informal sector & sold to buy-back centres; or if not collected is post-separated at MRF; residual waste transported to landfill.

Note that the Truck and Trailer option will not generally be feasible in cases where Rear End Loaders are used. Figure 1 provides a schematic representation of the S@S options included in the model. Costs and benefits associated with each of these options are assessed up until the point where recyclables have been sorted and baled at the MRF. Costs and benefits associated with downstream recycling/processing activities are not currently included in the model (as these will not differ between the options); nor are costs or benefits incurred by households. The model boundaries are represented by the two red vertical lines in Figure 1.

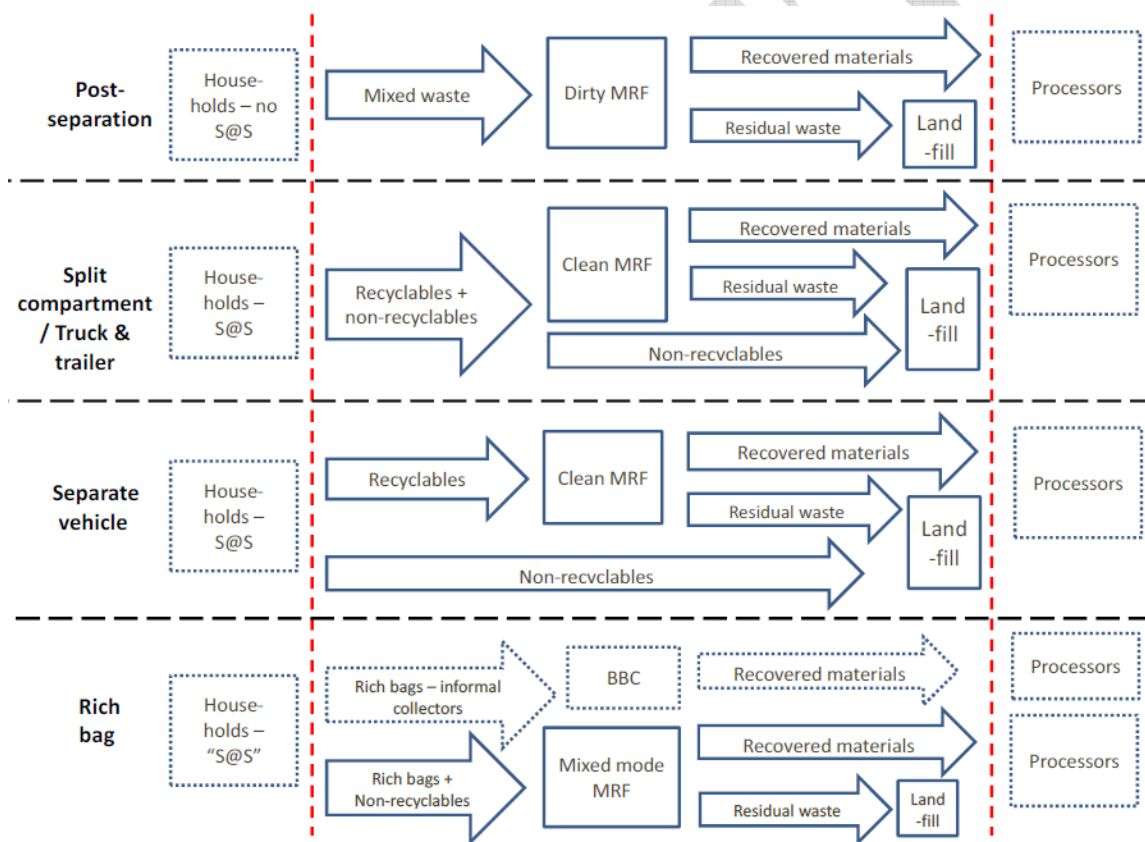


Figure 1: Separation at Source collection options assessed by the SASCOST model, and model boundaries

Based on user inputs, the model calculates the overall net cost or benefit of each of the S@S options (in Rands (R) per year, R per household/month and R per tonne), for a defined set of 5 suburbs within a specific municipality. This allows the user to identify which option would be most cost-effective for implementation within that specific set of suburbs. The model can be run multiple times in order to obtain results for other suburbs, and to assess alternative scenarios based on varying input values.

Version 1 of the model focuses on financial costs and benefits associated with source separation of post-consumer packaging waste (paper, plastic, glass and metals). Specifically, it assesses vehicle/collection costs; communication costs; container costs; costs of sorting at the MRF; and costs of transporting the residual fraction from the MRF to the landfill. In terms of benefits, it assesses the value of

the recovered recyclables, and savings in terms of reduced collection, transport and disposal of waste to landfill.

A second version of the model has also been developed (with funding from the Department of Science and Technology (DST) through the Waste Research Development and Innovation Roadmap), which expands on Version 1 by incorporating socio-economic and environmental costs and benefits ('externalities'), such as impacts on job creation, vehicle-related CO₂ emissions, and avoided externalities at the landfill site. This allows municipalities to assess trade-offs between the financial, socio-economic and environmental impacts of each option, and to identify the most appropriate option from a broader sustainability perspective.

INDICATIVE COSTS OF IMPLEMENTING SEPARATION AT SOURCE

The SASCOST model was originally intended as a decision support tool for use by municipalities to inform decisions regarding the appropriate option for implementing S@S. However, it has since been proposed that the model can be of value in providing information on the indicative costs of implementing S@S in different municipal contexts, and on the total costs of rolling out S@S nationwide. Indicative results on these costs are provided in the following sub-sections.

Indicative costs of implementing S@S for different types of municipalities

The Municipal Infrastructure Support Agency (MISA) has proposed that we use the model to provide information regarding the typical costs of implementing S@S (relative to the status quo) for different types of municipalities in different contexts (urban vs rural, small vs large etc.). The first step in doing this was to identify case study municipalities on which these indicative results should be based. Time and budget constraints for this study precluded the collection of primary data to populate the model from each municipality in the sample. Instead, we started with those municipalities for which we already have some relevant data (albeit incomplete, for the most part), and combined this with hypothetical data relating to the other input values required by the model. The aim was to ensure that we included a broad range of local municipalities varying in size, location (provincial representation across South Africa, urban vs rural), etc. Specifically, there is a need to include municipalities from category A (metro's), as well as the various category B municipalities (local municipalities, ranging from B1 to B4).

According to COGTA (2009), the relevant categories can be defined as follows:

- A: Metros: Large urban complexes with populations over 1 million
- B1: Local Municipalities with large budgets and containing secondary cities
- B2: Local Municipalities with a large town as a core
- B3: Local Municipalities with small towns, with relatively small population and significant proportion of urban population but with no large town as a core
- B4: Local Municipalities which are mainly rural with communal tenure and with, at most, one or two small towns in their area

As such, including municipalities from across these categories would ensure sufficient variation between small/large and urban/rural municipalities. It should be noted that the target for implementation of S@S in the National Waste Management Strategy only applies to metros, secondary cities and large towns (i.e. Category A, B1 and B2 municipalities); and not to smaller (B3 and B4) municipalities; and it could be assumed that this will apply similarly should DEA enact legislation to make S@S mandatory. However, given that MISA expressed the need to compare the costs of implementing S@S in smaller, rural municipalities relative to larger, more urbanized areas, we included local municipalities from across the full spectrum from A to B4. We also attempted to ensure a reasonable geographical spread across a number of different provinces.

For confidentiality reasons, we are unable to provide the names of the municipalities included in the sample; instead they will be referred to as Municipality 'a', Municipality 'b', etc. The sample consisted of seven municipalities in all, from four different provinces. It includes three metropolitan (Category A) municipalities, and four Category B municipalities, one from each sub-category (B1, B2, B3 and B4).

It is also important to take into account that, in addition to site-specific factors (such as income levels, number of households, distances travelled etc.), which will differ between municipalities (and even between suburbs within each municipality); the model results are also sensitive to a wide range of other factors; including participation rates in S@S, the type of vehicles used for collection, etc. Given that the results of the model vary depending on a number of factors; and the fact that we are relying on some hypothetical data, there is a need to be consistent regarding the assumptions and the hypothetical values used, in order to ensure we are comparing like-for-like between the municipalities.

In particular, we apply the following assumptions:

- In all cases we assume that the S@S programme is offered to a set of 5 middle-income suburbs. Typically S@S programmes are understood as likely to be more viable in high income areas (due to the higher proportion of recyclable packaged materials generated), and the model does allow comparison of high and low income areas, which would yield relevant information for decision making. However, focusing on the results for middle-income households only (where the costs will typically fall somewhere between those for high and low income households) facilitates easier aggregation to the national scale; based on the total number of households within each category of municipality; without having to distinguish further between high and low income households within each municipal category, for which data is not readily available.
- The assumed participation rate in all cases is set at 30% (i.e. of the households that are offered the S@S service, 30% of them participate on a regular basis).
- For the separate vehicle option, it is assumed throughout that 4 tonne trucks with trailers will be used for collecting recyclables; as this size of vehicle is generally seen to be the most efficient.
- To reflect the increasing distance to the market for recyclables in the case of outlying municipalities, we assume that the weighted average price paid per tonne of recyclables recovered in these areas will be lower than actual market prices paid for recyclables that have been delivered to recyclers. The model works with a weighted average price of approximately R1600 for materials baled and delivered to recyclers (given the typical composition of recyclables associated with middle-income households). As such, we assume that this price will be applicable in metros (category A municipalities); but that the price will be correspondingly lower in category B municipalities. Specifically, we apply a weighted average price for recyclables of R1000 per tonne in these municipalities, based on data from testing the model with some of the category B municipalities.

The model results are also very sensitive to the size of the MRF where recyclables are processed and recovered, with significant economies of scale coming into play (i.e., with a larger facility, the costs per tonne of waste processed and recovered are lower, due to improved efficiencies). In order to accurately reflect these economies of scale as they apply to municipalities of differing size, we apply the best available data that we have with respect to the size of the facility(ies) in each of the case study municipalities.

The results of this analysis are provided in Table 1. Note that the model is currently based on 2015 prices, but the results in this paper have been updated to 2018 values using Producer Price Index (PPI) inflation rates. It is clear from these results that, as expected, the cost of implementing S@S generally increases for smaller, more outlying municipalities as compared to larger metropolitan centres. There are a number of reasons for this, with the main reasons being as follows:

- In larger, more urbanized centres, there is a higher population density, and greater volumes of recyclable packaging materials being generated. This implies that there will be economies of scale both in terms of collection (collection vehicles can be utilized at full capacity, and can collect large volumes of materials within relatively short distances), and in the sizing of Materials Recovery Facilities (facilities processing larger volumes of waste operate at lower cost per tonne of waste processed), leading to increased efficiencies. These economies of scale are absent in the case of smaller municipalities, and in particular in more rural areas, where there are lower population densities, lower volumes of recyclables being produced, and greater distances that must be covered in collecting recyclables. In addition, MRFs will tend to be smaller, and will therefore have higher costs per tonne of waste processed.
- Markets for recyclables also tend to be located within larger urban centres; as such, in the case of outlying municipalities, there are additional transport costs associated with getting recyclables to the market.

Having said that, however, when interpreting the results, it is important to bear in mind that the costs are based on a very small-scale system, specifically, on the programme being run in only 5 suburbs. In this type of system, particularly in the case of smaller suburbs, economies of scale in collection cannot be achieved. In addition, the costing of the MRFs is generally based on the size of current facilities in operation. In the case of the smaller municipalities, current facilities tend to be too small to realise economies of scale, such that the resulting costs of the MRFs will be relatively high. As such, for all municipalities (and for the smaller municipalities in particular), the results should be seen as an over-estimate of actual likely costs. This is because with widespread rollout of S@S, the collection system, as well as the MRFs and other facilities, are likely to be designed (or should be designed) in such a way as to realise economies of scale, which will reduce the overall costs.

Finally, it is important to bear in mind that the results are largely based on hypothetical data, and should therefore be treated with caution.

Indicative costs of rolling out S@S at the national level

The previous sub-section provided indicative results regarding the costs of implementing S@S (per tonne of waste recovered, and per household per month) for a specific set of 5 middle income suburbs in each of seven case study municipalities, ranging from category A to B4 local municipalities.

In order to aggregate from these costs to the national level, we take the indicative costs per household per month in each of the representative municipal categories, and multiply these by the total number of households within each of these categories (and by 12 to obtain annual costs). In the case of the metros (category A), since there were three such municipalities in the sample, we take an average across the three, weighted by their respective populations. For the category B1-B4 municipalities, where we only have one case study municipality in each category, we assume the costs of our case study municipalities are representative of others in the same category.

As mentioned above, the decision to focus only on middle income suburbs (for which costs are likely to lie somewhere between those for high and low income suburbs) was made in order to facilitate this aggregation; without having to distinguish further between high and low income households within each municipal category, for which data is not readily available.

Data on the number of households within each category was obtained from Statistics South Africa (2017), which indicates that 44.6% of households in South Africa reside in the eight metros, 14.9% in B1 municipalities, 8.1% in B2, 12.9% in B3, and 19.6% in B4. With the total number of households in South Africa at 16 923 309 (Statistics South Africa, 2017), the number of households per municipal category can be calculated (see Column 2 of Table 2).

The results of aggregating the costs to the national level are presented in Table 2. The results suggest that the costs of rolling out S@S nationwide would range from approximately R4 billion to R6.2 billion, depending on the collection system. A total cost for the Truck and Trailer option was not provided, as this option is not relevant to all municipalities, given the existing fleet of waste collection vehicles.

Table 1: Indicative results: Cost of implementing S@S for different categories of municipalities

Category	Municipality	Cost ^a of each Separation at Source option							
		Post Separation		Truck and Trailer ^b		Separate Vehicle		Rich Bag	
		R/t of waste recovered	R/household/month	R/t of waste recovered	R/household/month	R/t of waste recovered	R/household/month	R/t of waste recovered	R/household/month
A	Municipality 'a'	3 355.99	9.64	N/A	N/A	5 916.15	17.00	5 201.78	14.94
A	Municipality 'b'	3 907.98	11.23	N/A	N/A	5 993.58	17.22	5 753.77	16.53
A	Municipality 'c'	3 555.49	10.21	N/A	N/A	6 472.91	18.60	5 401.28	15.52
B1	Municipality 'd'	2 950.36	8.48	N/A	N/A	8 110.22	23.30	4 796.15	13.78
B2	Municipality 'e'	5 168.03	14.85	6 653.80	19.12	10 659.26	30.62	7 013.82	20.15
B3	Municipality 'f'	11 582.44	33.28	11 202.56	32.18	14 436.21	41.48	13 428.23	38.58
B4	Municipality 'g'	14 774.43	42.45	13 776.64	39.58	20 762.37	59.65	16 620.23	47.75

Notes: (a) Results are based partially on hypothetical data and should therefore be treated with caution. Total cost takes into account vehicle/collection costs; communication costs; container costs; costs of sorting at the MRF; and costs of transporting the residual fraction from the MRF to the landfill. Benefits and savings are dealt with in a later section of the paper.

(b) "N/A" refers to cases where the truck and trailer option is not applicable (i.e. in the case of municipalities using compactors/rear-end loaders to collect waste).

Table 2: Indicative results: Aggregating cost of implementing S@S to the national level

Category	Number of households	Cost per household per month ^a				Cost per annum ^a – Total for South Africa			
		Post Separation	Truck and Trailer	Separate Vehicle	Rich Bag	Post Separation	Truck and Trailer	Separate Vehicle	Rich Bag
A^b	7 544 411	10.25	N/A	17.58	15.56	928 187 223	N/A	1 591 831 335	1 408 308 256
B1	2 518 188	8.48	N/A	23.30	13.78	256 250 849	N/A	704 085 471	416 407 630
B2	1 367 403	14.85	19.12	30.62	20.15	243 671 280	313 737 029	502 438 693	330 638 134
B3	2 179 722	33.28	32.18	41.48	38.58	870 493 857	841 721 524	1 084 978 522	1 009 124 189
B4	3 313 584	42.45	39.58	59.65	47.75	1 687 939 640	1 573 819 810	2 371 863 357	1 898 683 576
Weighted average^c		19.63		30.80	24.93				
Total for SA	16 923 309					3 986 542 849		6 255 197 378	5 063 161 786

Notes: (a) Results are based partially on hypothetical data and should therefore be treated with caution. Total cost takes into account vehicle/collection costs; communication costs; container costs; costs of sorting at the MRF; and costs of transporting the residual fraction from the MRF to the landfill.

(b) Cost per household per month for Category A is a weighted average over the three metros in the sample (based on relative population of each municipality)

(c) Weighted average costs across all categories are based on the number of households in each category.

However, as mentioned above, it is important to bear in mind that these results are largely based on hypothetical data, and should therefore be treated with caution. In addition, in the case of the category B municipalities, there is only one case study municipality represented from each sub-category; and as such, the results from each of these case study areas cannot necessarily be considered as representative; such that aggregation to the national scale should be done with extreme caution.

In particular, it is important to note that these results are likely to over-estimate the actual costs. As explained above, this is because the costs that were used as the basis for aggregation were based on small-scale systems; where economies of scale in collection cannot be achieved. On the other hand, with widespread rollout of S@S, the collection system, as well as the MRFs and other facilities, are likely to be designed (or should be designed) in such a way as to maximize on economies of scale, which will significantly reduce the overall costs of implementing S@S nationwide.

In addition, it is unlikely that the same type of system will be rolled out in all areas; instead, the most cost-effective option will differ from one area to another (the model can make area-specific recommendations in this regard), such that the actual costs of implementing S@S across the country may be lower than the total costs of each option indicated in Table 2, which assume that the same system is being applied nationwide.

Furthermore, the variation in costs between different categories of municipalities (see previous subsection) implies that, in some areas (e.g. smaller outlying municipalities), implementing S@S may simply not be viable. Focusing only on those municipalities where the costs of implementing S@S are reasonably low is likely to be far more cost-effective overall.

INCORPORATING BENEFITS, SAVINGS AND EXTERNALITIES

The SASCOST model provides information not only on the costs of Separation at Source, but the benefits and savings as well. The results presented up until this point focus purely on the financial costs. However, it is also important to take into account the benefits and savings associated with S@S. These include the value of the recovered materials; as well as savings associated with reduced collection (in normal waste collection vehicles), transport and disposal of waste to landfill. In Table 3, the information from Table 2 is expanded to also reflect the benefits (per household per month, and in total for countrywide implementation); as well as the overall net cost (costs less benefits).

Table 3: Net costs of implementing S@S: Incorporating benefits and savings

Category	Households	Cost per household per month ^a				Cost per annum ^a – Total for South Africa			
		Post-Sep	T&T	Sep. Veh.	Rich Bag	Post-Sep	T&T	Sep. Veh.	Rich Bag
A^b	7 544 411	10.25	N/A	17.58	15.56	928 187 223	N/A	1 591 831 335	1 408 308 256
B1	2 518 188	8.48	N/A	23.30	13.78	256 250 849	N/A	704 085 471	416 407 630
B2	1 367 403	14.85	19.12	30.62	20.15	243 671 280	313 737 029	502 438 693	330 638 134
B3	2 179 722	33.28	32.18	41.48	38.58	870 493 857	841 721 524	1 084 978 522	1 009 124 189
B4	3 313 584	42.45	39.58	59.65	47.75	1 687 939 640	1 573 819 810	2 371 863 357	1 898 683 576
Weighted average^c		19.63		30.80	24.93				
Total for SA	16 923 309					3 986 542 849		6 255 197 378	5 063 161 786
Category	Households	Benefit per household per month ^a				Benefit per annum ^a – Total for South Africa			
		Post-Sep	T&T	Sep. Veh.	Rich Bag	Post-Sep	T&T	Sep. Veh.	Rich Bag
A^b	7 544 411	9.94	N/A	7.64	9.94	899 816 030	N/A	691 899 994	899 816 030
B1	2 518 188	4.89	N/A	5.16	4.89	147 619 658	N/A	155 918 321	147 619 658
B2	1 367 403	7.22	4.87	5.04	7.22	118 528 154	79 955 389	82 710 586	118 528 154
B3	2 179 722	6.89	4.54	4.70	6.89	180 150 319	118 663 040	123 054 988	180 150 319
B4	3 313 584	5.68	4.11	4.28	5.68	225 810 483	163 495 735	170 172 315	225 810 483
Weighted average^c		7.74		6.03	7.74				
Total for SA	16 923 309					1 571 924 644		1 223 756 204	1 571 924 644
Category	Households	Net cost per household per month ^a				Cost per annum ^a – Total for South Africa			
		Post-Sep	T&T	Sep. Veh.	Rich Bag	Post-Sep	T&T	Sep. Veh.	Rich Bag
A^b	7 544 411	0.31	N/A	9.94	5.62	28 371 193	N/A	899 931 341	508 492 226
B1	2 518 188	3.59	N/A	18.14	8.89	108 631 191	N/A	548 167 150	268 787 972
B2	1 367 403	7.63	14.25	25.58	12.93	125 143 126	233 781 640	419 728 107	212 109 980
B3	2 179 722	26.39	27.64	36.78	31.69	690 343 538	723 058 484	961 923 534	828 973 870
B4	3 313 584	36.77	35.47	55.37	42.07	1 462 129 157	1 410 324 075	2 201 691 042	1 672 873 093
Weighted average^c		11.89		24.78	17.19				
Total for SA	16 923 309					2 414 618 205		5 031 441 174	3 491 237 141

Notes: (a) Results are based partially on hypothetical data and should therefore be treated with caution. Net cost refers to total costs (vehicle/collection costs, communication costs, container costs, costs of sorting at the MRF, and costs of transporting the residual fraction from the MRF to the landfill); less total benefits (value of the recovered recyclables; as well as savings in terms of reduced collection, transport and disposal of waste to landfill).

(b) Costs/benefits per household per month for Category A is a weighted average over the three metros in the sample (based on relative population)

(c) Weighted average costs across all categories are based on the number of households in each category.

Finally, as mentioned previously, an expanded version of the model, incorporating socio-economic and environmental impacts (externalities), has been developed; with funding from the DST Waste Research Development and Innovation Roadmap. Specifically, the following additional costs/benefits were incorporated in the model:

- Impacts of informal collectors on the viability of the S@S programme
- Impacts on employment and livelihoods (including formal job creation and informal sector livelihoods)
- Additional/avoided greenhouse gas emissions from collection and transport
- Avoided social and environmental externalities from landfill disposal

In addition, avoided landfill disposal costs (already included in Version 1) were expanded to account for the full value of landfill airspace savings and increased lifespan.

It is interesting to note how the incorporation of the socio-economic and environmental impacts changes the results of the model. In Version 1 of the model (financial costs and benefits only); most of the options yielded net costs (although in some scenarios, the truck and trailer option yields net benefits). For example, based on hypothetical data for a set of 5 high income suburbs in Municipality 'a', the cost of implementing S@S ranged from R3 356 per tonne of waste recovered through the post separation option, to R5 916 per tonne using a separate vehicle approach (see first row of Table 4). Taking into account financial benefits and savings (value of recovered materials; and savings from reduced collection, transport and disposal to landfill); the net costs range from R522 (post separation) to R3 339 (separate vehicle) per tonne of waste recovered (second row of Table 4).

In Version 2, however, with socio-economic and environmental impacts included, there is a big swing toward all options now yielding significant net *benefits* (see third row of Table 4). In the example of Municipality 'a', these benefits range from R10 159 per tonne for the rich bag option, to R15 910 for the separate vehicle option (which now becomes the most attractive option, owing mainly to the benefits associated with the large numbers of jobs created), based on the same set of hypothetical input data.

It should be noted, however, that these high net benefits are disproportionately dominated by the benefits associated with downstream, indirect and induced job creation; for which there is an argument for excluding from the model results. This is particularly evident in the case of the separate vehicle option, for which there is additional job creation associated with collection (which in turn has a knock-on effect in terms of indirect and induced job creation), which is not the case for the other options. Even excluding these benefits, however, S@S does appear more favourable when socio-economic and environmental impacts are considered as compared to when only financial considerations are taken into account. For example, in the case of Municipality 'a', (bottom row of Table 4), there is a net benefit for some options (e.g. the post separation option shows a net benefit of R927 per tonne); and a net cost of only R370 per tonne for the separate vehicle option (as compared to R3 339 per tonne when only financial costs and benefits are considered).

Table 4: Comparison of net cost (or benefit) of S@S per tonne of recyclables recovered for Municipality 'a' when socio-economic and environmental impacts are excluded/included

	Post separation	Truck & trailer	Separate vehicle	Rich bag
Version 1: Financial costs only	3 355.99	N/A	5 916.15	5 201.78
Version 1: Net costs (costs less benefits) based on financial costs/benefits only	522.02	N/A	3 339.34	2 367.81
Version 2: Net benefit with socio-economic and environmental impacts included	(12 005.43)	N/A	(15 910.26)	(10 159.64)
Version 2: Net cost (or benefit) with downstream, indirect and induced job creation excluded	(926.84)	N/A	370.48	918.95

Note: Figures in parenthesis indicate a net benefit. Results are based partially on hypothetical data and results should therefore be treated with caution.

CONCLUSIONS AND FURTHER RESEARCH

The above analysis suggests that the net cost (costs less benefits) of S@S varies significantly depending on the type of collection system (post separation, truck and trailer, separate vehicle or 'rich bag'), and on the type of municipality. For example, for a separate collection system, the additional cost of implementing a separate vehicle system ranges from R17 per household per month (Category A municipalities), to R60 per household per month (Category B4 municipalities); based purely on financial costs. Aggregating these costs to the national level, the results suggest that the costs of rolling out S@S nationwide would range from approximately R4 billion to R6.2 billion, depending on the type of collection system. (Note that these results are based on hypothetical data and should therefore be treated with extreme caution).

However, these results are likely to over-estimate the actual costs; as potential economies of scale are not properly accounted for; nor are the efficiencies that will be achieved by adopting a tailored approach to each area. In particular, S@S should not be implemented where costs are prohibitively high (e.g. smaller outlying municipalities). Instead, the initial focus should be on the 'low-hanging fruit,' namely metros, where the bulk of the recyclables are generated, where population densities allow for efficiencies in collection and economies of scale to be achieved, and where there is easier access to markets.

In addition, the benefits and savings associated with S@S also need to be taken into account. In particular, when socio-economic and environmental impacts are included, there is a big swing toward all systems yielding significant net benefits. Even excluding the benefits associated with downstream, indirect and induced job creation, which disproportionately dominate the results, S@S does appear more favourable when socio-economic and environmental impacts are considered; with all options showing higher net benefits or lower net costs as compared to when only financial costs and benefits are considered.

However, there are a number of ways in which the model needs to be updated, expanded or further refined. For example, going forward, the model will be redesigned in such a way that the user can more easily select which perspective should be taken into account (e.g. municipal perspective vs. national socio-economic perspective); or at least which specific categories of costs/benefits should be included in the overall cost benefit calculation (e.g. to focus only on financial costs and benefits, vs including socio-economic and environmental impacts). Since the "Results" tab of the model presents an itemized account of costs and benefits, it is possible for the user to exclude those categories of costs/benefits that are not relevant to their decision making; although currently this needs to be done manually. Going forward, the model will be redesigned in such a way as to more easily allow for this flexibility.

Furthermore, the model should allow for each variable to be 'weighted' according to the municipality's specific needs and priorities (for example, a specific municipality may want to give more weight to job creation potential as compared to environmental impacts). This will allow municipalities to make more informed decisions regarding source separation from an integrated financial, economic, social and environmental perspective; taking into account their specific needs and priorities.

In addition, many of the values in the model need to be updated – Version 1 of the model was originally developed in 2015, and many of the values are due for an update. For example, although the results in this paper have been inflated to 2018 values based on PPI inflation rates; for the most part, the monetary values in the model itself are still based on 2015 prices. These will need to be updated to 2018 prices as part of the further refinement of the model.

Finally, the scope of the model could also be expanded. Currently, it focuses on packaging waste (paper, plastics, glass and metals) from households; however, a clear need has been expressed to expand the model to incorporate other waste sources and streams, particularly organic waste, which is increasingly seen as being a key waste stream to target under a S@S programme. In addition, feedback from municipalities and others suggests that there is a need to assess a broader range of options within the model; including drop-off facilities; retro-fitting existing waste-collection vehicles to allow dual collection in multiple compartments; and the procurement of specialized split-compartment compactor vehicles. Finally, with the exception of job creation benefits, the model currently only assesses costs and benefits from the point where recyclables are collected to the point where they are baled at the MRF and sold to processors; the costs and benefits associated with downstream activities are excluded. There have been

some suggestions that the model boundaries should be expanded to consider the full value chain (including downstream recycling and processing).

ACKNOWLEDGEMENTS

The authors would like to gratefully thank the funders of this research, specifically the CSIR (through the Strategic Research Panel), and the Department of Science and Technology (through the Waste Research, Development and Innovation Roadmap). We would also like to thank Linda Godfrey and Zanele Tshwete (CSIR Implementation Unit) as well as Themba Dladla and colleagues from the Municipal Infrastructure Support Agency (MISA) for their suggestions regarding application of the model. Finally, we would like to thank the anonymous reviewers for useful comments on an earlier draft.

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