WasteCon 2020

SCIENTIFIC REVIEW

The WasteCon 2020 Technical Sub-Committee comprised of the following individuals:

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In compiling the scientific programme for WasteCon 2020, every effort has been made to reflect the Conference theme, "*Circular Economy – Can we close the loop?*" and to provide persons from all waste management disciplines an opportunity to have access to matters in the industry. We trust that all will find the scientific content of the proceedings informative, meaningful and challenging and that they will take with them new methods and modern strategies that they can utilize in their environment.

The WasteCon 2020 Technical Sub-Committee oversaw the entire peer review process for the papers. Each member was appointed as an assessor and made use of reviewers selected from leading waste and environmental scientists, engineers, practitioners and professionals all of whom practice in the waste management field. Every effort was made to ensure that the reviewing process was fair and open, with the aim of maintaining the high standard of WasteCon and helping authors to develop and improve their work so that the sharing of their experience, expertise and research will enhance the flow of knowledge in the waste management community.

ABSTRACTS

An invitation to submit abstracts for WasteCon 2020 was done one year in advance. The abstracts were evaluated by the WasteCon Organising Committee for applicability to the conference for proposed oral or poster presentation. Their experience in the evaluation of abstract stretches over more than 20 years.

ORAL PAPER PRESENTATION

After acceptance of the abstracts, authors of abstracts were notified if it was accepted or not via email. Authors were then invited to submit full papers and were provided with detailed instructions for the submission of full-length academic articles subjected to a blind peer review process. The WasteCon 2020 Technical Review Committee appointed for the review process consists of its members who are experts in the field and who are from different academic institutions or experts from specialised companies and consist of leading waste and environmental scientists, engineers, practitioners and professionals in the waste industry.

Authors were provided with detailed instructions of the stringent review process:

- papers were submitted via email to the WasteCon Organising Committee;
- each paper was submitted to reviewers
- a timeframe was provided for the review
- comments on the papers were submitted by the reviewers to the WasteCon Organising Committee using a prescribed format for comments and the option to accept or reject the paper (all papers submitted were reviewed and accepted or rejected (usually with an option to improve and be accepted after corrections);
- the comments were sent back to the authors via email by the WasteCon Organising Committee informing them of the outcome;
- the authors were given a timeframe in which to resubmit papers if needed.
- All review comments were shared with the author for improvement or correction.

The selection of reviewed papers are recommended by the Technical Review Committee who selected the final papers for publication. These are scientific, scholarly papers, resembling original research from academia, industry and businesses. The fields covered include technical, industry, theoretical and academic fields and were focused on a specific theme of the conference.

As with previous WasteCon Conferences, which have become widely recognised as the waste management forum for the industry in Africa, the Committee has strived to continue the tradition. In total, 63 abstracts were originally submitted, unfortunately it is not possible to accommodate all and regretfully some papers were not accepted. The final programme incorporates 52 oral papers, some that will be presented during 3 specialised webinar sessions. These sessions will provide a platform of interactive discussions and participation through various webinars planned to be run during 2021.

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WasteCon 2020

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RESIDENTIAL WASTE ESTIMATION USING DISAGGREGATE HOUSEHOLD DATA

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ABSTRACT

Many South African municipalities still fail to provide reliable, scheduled waste collection services to their residents. A fundamental building block to address the operational logistics of residential waste collection is to estimate the demand for waste collection services robustly. Although seemingly straightforward, the process is costly and time-consuming. Often the time required to capture sampled data is much longer than the useful life of the gathered data. In response, waste management planners usually follow a top-down approach, estimating the waste at the city and regional levels. Unfortunately, such estimates are of little value when disaggregated as the allocation towards lower levels, like suburbs, often cannot reliably take the diversity into account that affects the demand for waste collection. In this paper, we present an alternative approach. The article explains how detailed synthetic populations, which are accurate at both household and individual level, can be generated in a repeatable and reproducible manner from publicly available data sources. We then use household attributes affecting the demand for waste collection to demonstrate the prediction of waste generated at a disaggregate level.

KEYWORDS

Waste Generation, Synthetic population, Household, Municipal Solid Waste.

INTRODUCTION

While South African policies at all spheres of government promote sustainability and improved waste management, we have not followed it up with the necessary efforts to have a deep(er) understanding about how waste is generated (Beigl et al., 2008). The first step in planning waste management services is to have a fair idea of the quantity of waste generated along one or more material or collection streams. Unlike other municipal services like water and electricity, it is not possible to measure waste generated on a (near)-continuous and detailed level. Consequently, our estimates often rely on small, costly and spatially incomplete samples and surveys from which one then estimate models.

One consequence of having to rely on small and costly field studies, as Beigl et al. (2008) review in their article, is that there can be a delay of up to 12 years from when the data was collected to when they fitted the models. Since the urban landscape changes a lot more dynamically in terms of population distributions, it is necessary to find more dynamic approaches to waste estimation.

Research rarely performs household-level waste estimation and literature cite limited Census data and the associated information privacy as the main reason. That is true. This paper demonstrates how detailed synthetic populations, which are accurate at both household and individual level and, more recently, publicly available, can be used to estimate waste generation. While one can extend the disaggregate, household-based model to cover different material or collection streams, this manuscript will report specifically on two models that aim to estimate residual (commingled) residential waste generated by households (only) for curbside collection.

The next section explains the process of generating synthetic populations. We then introduce two fairly simplistic waste generation models that both benefit from knowing the detailed household structure. Both models allow for random sampling and, therefore, also allows this paper to perform and report on the validation over multiple instances. The paper concludes with a research agenda towards making the work more accessible to local authorities.

POPULATION SYNTHESIS

Current waste estimation models are frequently aggregate and top-down. That is, they start the estimation process from a higher order, large administrative unit. Authorities, having access to the land parcel data, can establish the homogeneity of settlement density and the dwelling types in a given area. Aggregate data is assumed to implicitly control and account for more detailed household-variables like income, employment status and household size. While this may be true in developed countries, the socioeconomic inequality in South Africa suggests that research and planners take the more detailed household attributes into account.

One data-related problem is that Census data is, in its raw form, is not that valuable for waste estimation. The problem with the data is that one cannot easily establish household composition at a detailed level. Census data is made available in two forms. The first is the aggregate, Community Profiles sub place tables, which provides totals (for different variables) for suburbs or sections of a township (Statistics South Africa, 2015). For example, the tables may tell you how many people associate with being a male, female, or person with an unspecified gender in each particular sub place. Or, how many people reported to be discouraged work-seekers. The second form of the Census data is the more detailed 10% public use micro-sample (PUMS). This data set includes detailed records for a random sample of individuals, but the geographic level of detail is limited to the main place. The reason for the aggregation is to protect individual privacy.

The process of population synthesis deals with using these two forms of Census data to, essentially, reverse engineer the aggregation process and generate (synthesise) a detailed, richly described population at a high level of geographic detail. The process has two main stages (Müller & Axhausen, 2016). The first, fitting, aims to characterise the multiway distribution of all the attributes of interest by using the micro-sample and marginal information available. Joubert (2018) followed a Bayesian Network approach to estimate the conditional probabilities for different household types. The three household types included single-member households, those in which there is a single clear head of household role, and those in which there are dual head-of household roles. The second stage, generation, is then concerned with generating a stock of individuals (linked to households) by sampling from the fitted distributions. The result is, as Müller & Axhausen (2016) demonstrated, a synthetic population that is accurate at both individual and household levels. That is, the households are good representations of what one observes in the aggregated Census data, and the individuals making up those households, are also good representations of the Census records. The value of the Bayesian Network approach is that it is a data-driven approach where one learns the structure of the model from the data instead of imposed some model structure a priori on the data. The benefit of using Bayesian Networks for the generation stage is that given the conditional probabilities estimated; one can synthesise households with structures and compositions that differ from the original observed Census data.

Joubert (2018) generated 100 synthetic populations for each of 9 municipal/metropolitan/provincial areas that include the whole of Gauteng, Buffalo City, City of Cape Town, eThekwini, Mangaung, Mbombela, Nelson Mandela Bay, Polokwane and Rustenburg. The open data is available in an extensible markup language (XML) format so that it can be parsed and read into a variety of software applications. An excerpt of the data, which depicts a household with an `id="8"`, is shown in Figure 1. This household has two members, persons 33 and 34, and has access to a private car. A coordinate (in the World Geodesic System of 1984, decimal degrees), referred to as `homeCoordWgs84`, estimates the household location as a randomly sampled point inside the sub place. The main dwelling type, its number of rooms, tenure status, and attributes related to running water and the sewerage connection are all given as household attributes.


```xml
<household id="8">
        <members>
                <personId refId="33"/>
                <personId refId="34"/>
        </members>
        <income currency="ZAR" period="year">
                        76800.0
        </income>
        <attributes>
                <attribute name="carAccess" class="java.lang.String" >Yes</attribute>
                <attribute name="dwellingTenure" class="java.lang.String" >OwnedPaying</attribute>
                <attribute name="homeCoordWgs84" class="org.matsim.api.core.v01.Coord" >(18.681390;-33.534571)</attribute>
                <attribute name="housingType" class="java.lang.String" >House</attribute>
                <attribute name="mainDwellingType" class="java.lang.String" >FormalHouse</attribute>
                <attribute name="numberOfDwellingRooms" class="java.lang.String" >2</attribute>
                <attribute name="pipedWater" class="java.lang.String" >Piped_dwelling</attribute>
                <attribute name="toilet" class="java.lang.String" >Flush_sewerage</attribute>
        </attributes>
</household>
```


Figure 1: Example of a household and its attributes in the extensible markup language (XML) format.

As an example, Figure 2 then depicts the individual attributes of one of the household members, namely person 34: a 21-year-old Coloured female who completed her secondary education and is currently not studying but working.


```xml
<person id="34">
        <attributes>
                <attribute name="age" class="java.lang.Integer" >21</attribute>
                <attribute name="completedEducation" class="java.lang.String" >Secondary</attribute>
                <attribute name="currentEducation" class="java.lang.String" >None</attribute>
                <attribute name="employed" class="java.lang.String" >true</attribute>
                <attribute name="gender" class="java.lang.String" >Female</attribute>
                <attribute name="householdId" class="java.lang.String" >8</attribute>
                <attribute name="personIncome" class="java.lang.String" >Income_77K</attribute>
                <attribute name="race" class="java.lang.String" >Coloured</attribute>
        </attributes>
</person>
```


Figure 2: Example of a person and her attributes in the extensible markup language (XML) format.

In the original data made available in the public domain, Joubert (2018) used the Census 2011 totals and only a limited number of household attributes. As part of this manuscript, the second version now reflects 2019 population totals (using the Statistics South Africa's Mid-year population estimates as growth factors). Also, it adds `carAccess`, `pipedWater` and `toilet` as additional attributes.

WASTE ESTIMATION

In this section, we demonstrate three waste generation models, based on varying levels of detail. This paper implements the waste calculation function as a Java interface with a single method, `estimateWaste(Household household)`, which takes a single argument: the household container.

The container reflects the contents of a household as parsed from the XML file. As an *interface* (an abstract Java type), and attributing to its inheritance functionality in object-oriented programming, one can implement the *class* (a less abstract, concrete Java type) a variety of contexts provided that one pass at least a household container.

Fixed quantity

In this first demonstration, we will use a fixed quantity of waste per household member and test the waste generation on all (100) synthetic populations for the City of Cape Town. The chosen value of 0.56kg/person/day is from Dennison et al. (1998). The per capita value is multiplied by 7 to represent a weekly waste generation. The weekly period allows the decision-maker to later assign the households to road segments and design weekly service delivery beats and routes. For each synthetic population, one only needs to parse the household file (`households.xml.gz`) since the household container already reflects all the household members' identification (Id) numbers. Here the Id is a sequential number starting from 0 with no relation to any real person's national identity number.

For each synthetic population, the procedure iterates through each household, passing the household container to the estimating calculator. In this simple form, the total household waste generated is merely the number of household members multiplied by the fixed value. The household's estimated waste is, for this paper, only added to the total. Using multiple populations allows a person to account for the inherent population dynamics as each used a different random seed during its generation stage. As a result, the planner obtains a distribution of waste generated instead of a single scalar value. Figure 3 shows the histogram of the estimated waste, along with the best-fit Gaussian distribution.

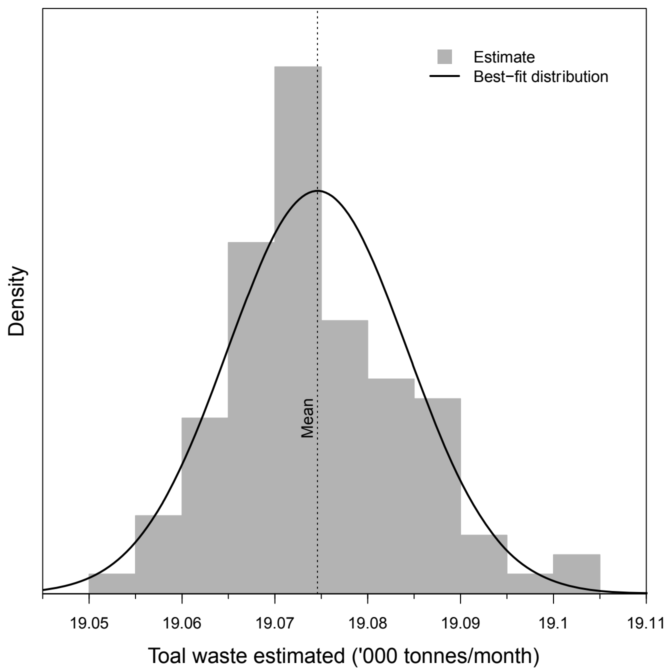

Figure 3: Distribution of weekly waste estimates when using a fixed per capita waste quantity.

Household size

Next, we use household attributes to demonstrate the capability of using synthetic populations. Dennison et al. (1996) estimate the Irish per capita household weight for different household sizes (Table 1).

Table 1: Household waste generation as a function of household size (Dennison et al., 1996).

Household size	Mean waste production per household (kg/week)	Per capita waste generation (kg/person/day)
1 person	7.1	1.01
2 persons	11.3	0.81
3 persons	13.0	0.62
4 persons	14.7	0.53
5 persons	16.4	0.47
6+ persons	17.9	0.43

Since each household container reflects the member Ids, one can easily find the household size for each. For each of the synthetic populations, the procedure iterates through each household; locates the correct per capita waste quantity based on the number of household members, and multiplies it with the household size to get its generated waste. Figure 4 shows the histogram of the estimated waste, again with the best-fit distribution. The values are quite similar the that of fixed quantities per person.

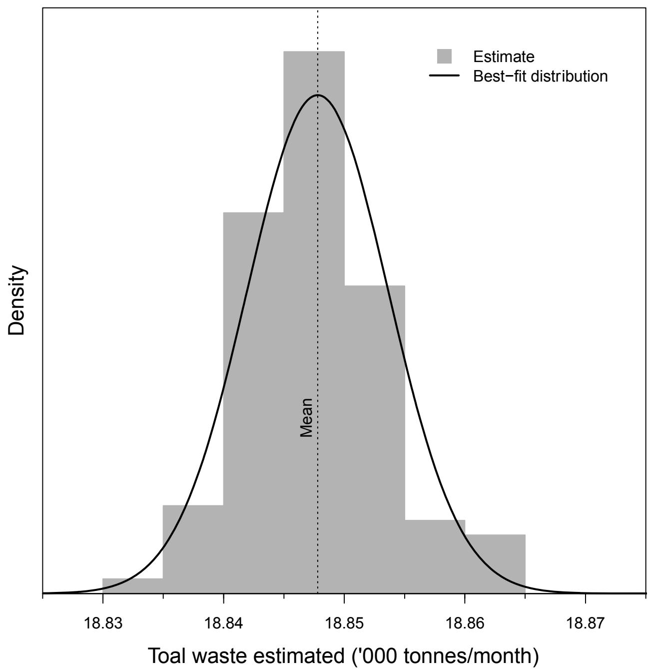

Figure 4: Distribution of weekly waste estimates when using a per capita waste quantity that is based on the specific household size.

Household age distribution

In the third application, we consider both household and individual attributes. For this we also parse the persons data (`population.xml.gz`). There does not seem to be a clear message, from literature, about the effect that the age distribution plays. While its importance is generally acknowledged, Beigl et al. (2008) suggest that the significant waste generators are households with children aged under 10. Their case study focused on multi-household dwellings in Austria. One case study showed that when the percentage of families with children under 10-years increases from 26% to 62%, the per capita waste grows by 128%. A more recent but still European-focussed effort in Poland suggests that the working-age population (aged 15-64) are the major contributors to household waste (Antczak, 2020). This paper postulates that it is the aggregated approach in estimation that influences the results and the subsequent discrepancy. Finding the correct parameter values for the South African context, while necessary, falls outside the scope of this paper. Here the emphasis is on showing that the disaggregated approach to waste generation can indeed accommodate the detailed attributes. Consequently, for this demonstration, we will adjust the per capita rates in a way described in the next paragraphs.

In the same way as the previous demonstration, the procedure iterates through each household and calculates the per capita waste. But now, the per capita waste is adjusted based on the age of the members. If a family has no children (persons under the age of 18), the per capita waste is adjusted downwards and multiplied by 0.8; in line with the literature suggesting young couples generate less waste (at home). Families with children under 10 (in line with Beigl et al., 2008) have their per capita waste multiplied by 1.2. Families with retired members (65+) have their waste multiplied by 0.9 as these families may still have (older) children, but the literature suggests this age group generates less waste.

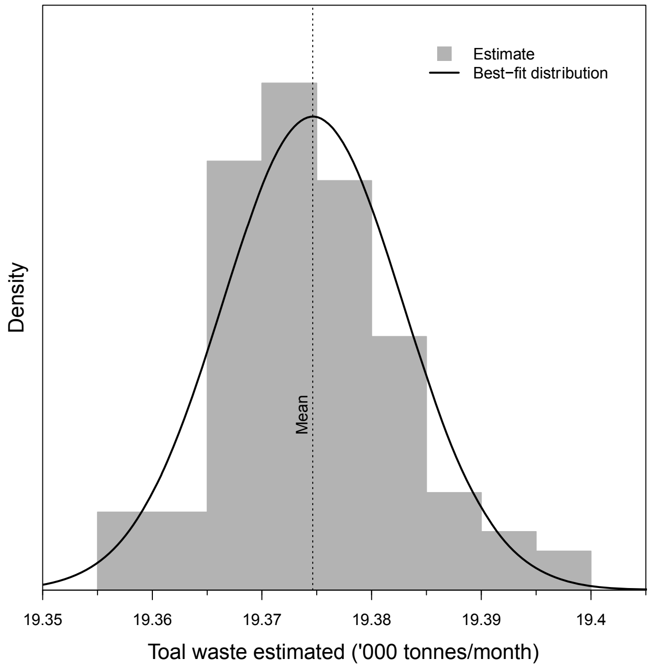

Figure 5: Distribution of weekly waste estimates when using the age distribution of the household members.

Figure 5 shows the histogram of the estimated waste, again with the best-fit distribution. The values are, also, similar to that of the other two approaches.

The question, though, is how well these waste estimates compare to actual data from the City of Cape Town? The first response would be "what data?" since there are multiple sources. Two, in particular, can be considered reliable, but disagree on the monthly quantities. The Integrated Waste Management Plan (IWMP) of the City of Cape Town (2015) predicts waste estimates from 2015 onwards. The IWMP's predicted weekly waste for 2019 would be approximately 21,600 tonnes. This estimate accounts for growth in waste (as a result of population growth and growth in waste per capita); factors in that about 47% of all waste are residential, and that Cape Town reports providing at least 94.3% of its citizens with (at least) weekly services. The actual waste disposal (available on Cape Town's open data portal at `https://odp.capetown.gov.za/datasets/waste-disposal`) suggest a much lower 11,500 tonnes per week (average over the last six months reported: January to June 2020). Still, the estimates provided in these three simplistic demonstrations (without accounting for any growth) are already well within a good range of available data. Better yet, the demonstrated estimates are at the household level, each with a detailed coordinate. The spatial detail, therefore, allows not only grand aggregates as we have from the current records, at the municipal level, but one can go down to the parcel, street, or neighbourhood level.

CONCLUSION

With detailed and richly described synthetic populations available for South African municipalities, there is ample opportunity to prepare not merely accurate, but useful waste generation estimates. Not only can one estimate quantities, but by building on recent and locally relevant work like that of Volschenck (2020), one will also be able to predict the willingness of households to participate in Curbside Recycling initiatives. The fact that the synthetic populations are available in a variety of metropolitan and provincial areas in South Africa allows many local authorities to benefit from repeatable and reproducible work.

Several next steps are on our radar now. Firstly, what none of the demonstrated approaches includes is a random component to account for within-household variation from week to week. Secondly, while the machinery now exists to estimate waste at the household level, this paper still applied (outdated) international parameters. How different are South Africa and its citizens' waste profile? How does economic inequality manifest itself in per capita waste generation parameters? These are questions needing answers in the South African context, and authorities need to launch efforts to estimate these. Once calculated, the mechanisms and supporting competency exists to provide high-resolution waste estimates.

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