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Rural solid waste in the Western Cape

J.H. van der Merwe and I. Steyl, South Africa

Solid waste as a management problem is mostly perceived to be an urban problem. This can be attributed to the concentration of industrial and human waste producers there, as well as to the fact that urban waste is managed. Rural waste is more often than not ignored, or at best is shoddily managed. The Western Cape offers a special challenge, with its aesthetically and agriculturally highly sensitive and valuable landscape accommodating a large rural population at fairly high density. In the virtual absence of public waste removal services, private waste management practice is bound to be marginal and to produce environmental and especially water pollution impacts. Questionnaire and field surveys of 350 land owners were therefore conducted to establish the extent of rural waste generation and to devise a management strategy for a study area covering the Stellenbosch district on the outskirts of Cape Town. The project is reported in full by Steyl (1996).

The survey and extent of waste

Because the extent of agricultural and industrial waste production is seasonally skewed and proved to be difficult to calculate, this paper deals with household waste generation in the region only. Utilising 1991 census results, the total population of 29 994 (61 persons per km^2) were collated per census ward as the primary spatial units of analysis. Since the amount of waste produced varies according to socio-economic class, the income structure was analysed to enable the division of the 7652 households in two socio-economic groups. The 4185 (55 per cent) households earning less than R12000-00 per year were considered low-income, with the balance being high-income. The waste generation rate for the groups was taken as 0,3 kg/person/day for the low-income group and 0,7 kg/person/day for the high-income group (based on urban figures reported by the Palmer Development Group (1995)). Using the formula:

$$x_i = \Sigma^n(axd)$$

where

x_i = total waste (kg)
a = people per household
d = group waste factor

and

n = ward number

the amount of waste per ward was calculated. This yielded the total amount of approximately 100 tons of household waste per week for the region.

Current waste management strategies

Analysis of waste storage, removal and disposal practices revealed significant flaws in the current management strategies employed. Bins (60 per cent) and bags are predominantly used for on-site storage, but the problem is that more than 35 per cent of respondents dispose of these at intervals exceeding one week. Since nearly 90 per cent of all properties are serviced by owners themselves, more than 60 per cent report burning and about 30 per cent dumping or burying as disposal techniques. Virtually no recycling takes place and this is not seriously considered as an alternative. However, the fact that 34 per cent of owners reported 'serious' waste management problems, and that 32 per cent regard their disposal sites as 'unsuitable' show encouraging awareness of flaws in the existing system.

When respondents were requested to rate the suitability of their disposal sites according to criteria taken over from the list of 'fatal flaws' contained in the DWAandF (1994) guidelines for waste disposal sites, the only factors gaining recognition from more than 80 per cent of respondents were invisibility (out of sight, out of mind?) and different water contamination threats. Factors like terrain relief and soil permeability were not considered important. The presence of aesthetically and environmentally unhealthy waste accumulation and handling witnessed during the research survey, stem from the practices and mind sets exposed above.

Researching a removal system

Along with the new local government dispensation in South Africa, service provision in the public sector seems set for new initiatives and an urgency to shake off urban bias in that sphere. Hence, the local Winelands District Council has expressed its intention to expand its waste removal service in the rural area under study. This service is presently so low-key in extent that 74 per cent of respondents were unaware of its existence! It is towards the spatial planning of such a system that the research was aimed. The rural character of the study area makes it imperative that a system of distributed relay stations be established as part of a total solid waste management system (SWMS). This procedure is generally practiced and reported on elsewhere (Steels 1988; Vesilend *et al* 1994). To these stations the individual waste generators may deliver their waste for short-term storage, and from them a centralised service may then collect and dispose of the waste at regional dumpsites.

The spatial nature of the problem to be solved suggested the application of a geographical information system (GIS) as the appropriate technology for system modelling. The modelling task involves two distinct analytical steps, namely locating suitable sites for the right number of transfer stations and finally assigning waste generation zones to each transfer station. The Idrisi GIS (since Version 4.1) and PC ARC/INFO packages offer the tools necessary for these tasks.

Locating waste transfer stations

The multi-criteria analysis (MCE) technique has been applied towards location studies for some time (Carver 1991) and for transfer station location in particular (Massam 1991), but has only recently been incorporated into commercial GIS packages. Provided that a proper digital spatial data base exists, the modelling procedure progresses through a number of predetermined steps, as summarised in Table 1 below. The procedure then produces a suitability map of the region, indicating the best potential locations for the facilities in question.

From the list of criteria determining site suitability for station location, as compiled by Massam (1991:28), three factors could be operationalised in digital map form for this exercise. For each criterion, spatial raster images were created with assigned cell values between 0 and 5, which correlate with the potential of cells for station location according to that particular criterion. The first criterion was *road type*, where cells containing national roads were rated 1 (no potential for relay stations on the national road!) and main roads receiving 5 (regional tarred roads suitable for cost-effective transportation). Secondly, the *amount of waste* per census ward was divided into quintile classes, with the highest volumes receiving the value 5 and the lowest 1. The *distance to farms* was the third criterion. Since respondents had indicated 5000m as the limit to which they would be prepared to deliver waste to a transfer station, areas beyond this distance were constrained out from the image and shorter distances were given higher potential values. Further constraints were added to the model by assigning zero-values to all non-vacant land, to force station location onto existing vacant land only.

These factors were then given slightly varying weights according to economic consideration for the final suitability calculation. Road type, road distance and waste volume was the order of importance when the Idrisi MCE procedure was executed. Since the cell size of the images was 150m square, yielding 31980 cells in the 71955 ha study area, the suitability of individual 2,25 ha units were computed. A five-class suitability map, with a total of only 277 ha found to be in various degrees of the 'suitable' categories and 40 ha being labelled 'strongly suitable', was the result. From this map the most suitable 16 locations providing adequate spatial coverage of the study area could be selected. What remained was for waste production areas to be assigned to each transfer station.

Table 1. The formal steps in multi-criteria evaluation

Step in MCE procedure	*Actions*
1. Select suitability criteria	See discussion below
2. Establish the digital data base	Map, digitise, rasterise
3. Standardise potential values	Correlate image value with potential
3. Weight criteria	Assign differentiated importance
4. Run MCE program	Produce suitability map
5. Allocate regions to stations	Allocation map

Allocating waste sources to transfer stations

The task of allocating target areas to specific facilities is done through location-allocation modelling. All such techniques have one thing in common - some distance function (*e.g.* time or travel cost) is optimised (Gore 1991). Network analysis, through *path-finding* procedures, then determines optimum routes between points, while *allocation* determines the best station to serve given areas. Since employing a range of different criteria can yield various optimality patterns, two travel distances - from waste generator to transfer station and from transfer station to dump site - was deemed the important criteria here. Transfer stations were assigned waste demand capacity to constrain waste volume allocation to individual stations. This constraint was based on the current waste collection frequency (once a week) and removal vehicle load capacities (12000 kg).

The actual modelling was computed by means of PC Arc/Info's ALLOCATION module in PC NETWORK. The network database consisted of the road network coverage with each road segment having a proportion of the weekly volume of waste in adjoining census wards assigned to it. After various experiments to ensure that no waste generator had to travel more than 5 km to the nearest transfer station, final allocations were made. The results showed that none of the 16 transfer stations reached the capacity target of 12000 kg per week, with an average of 5780 kg and a minimum of 2964 being attained. This is of course the result of trying to satisfy vehicle capacity and delivery travel distance of waste generators demands at the same time. The use of smaller capacity vehicles may be the most profitable adjustment to this dilemma. A final analytical step would have been to use the ROUTE module of the program to compute the optimum collection routes for vehicles. Since there is much uncertainty about the future collection system and the availability of specific technologies for compaction, storage and transport, such experimentation seemed too far removed from reality to be considered at this time.

Conclusion

Rural waste is no doubt a serious and growing environmental problem in South Africa and it needs to be addressed. Scientific research for addressing waste service systems as part of wider waste management strategies is a necessary and productive field for research as has been demonstrated here. Use of modelling techniques, such as MCE, and packaged as tools in the fast developing field of GIS, ensures scientific rigour in planning through the application of decision-making rules ensuring efficiency and objectivity in final decision-making. That does not mean that decision-making is moving back into the incomprehensible and esoteric realms of 'scientistry'. Experimentation elsewhere is successfully developing means to employ public participation in the application of these technologies - making productive, sophisticated technology into appropriate technology.

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J.H. VAN DER MERWE, University of Stellenbosch.
I. STEYL, University of Stellenbosch.