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Full Length Research Paper

Modeling the generation of domestic waste for supporting the planning of municipal waste services

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The Polokwane declaration on waste management is to stabilize waste generation and reduce the waste disposal by 50% by 2012 and develop a zero plan for zero waste by 2022 waste generation is an ongoing process which will continue, as long as humans exist. The types and quantity of waste generated in South Africa have however, changed over time often leading to constraints in municipal waste management budgets as this may not have been expected at the time of planning or budgeting. The technological advancement, emergency of affluent communities and rapid urbanization have contributed to the significant increase in waste generation per capita. At times the projected resources for waste management have proven inadequate resulting in poor service delivery by municipalities. This work seeks to make an estimate projection of the future waste quantities and generation rate to present an opportunity to make appropriate financial allocations for future waste management systems. The work demonstrates that at varying recycling rate (> zero) waste reaching the disposal site reduces gradually. The proposed model reflects that with appropriate policies in place, accurate waste management planning and resource allocation can be achieved.

Key words: Waste disposal, communities, projections, waste management systems, budgets, technology advancement.

INTRODUCTION

While it has been possible to gather the current waste generation statistics for some municipalities in South Africa based on information from waste disposed of at municipal landfills, not all municipalities have weighbridges on their landfills (Deat, 2005), resulting in poor or little data on which to base predictions. One reason why the quantities of future waste generation should be estimated in time is the ever increasing complexity of waste and waste volumes ultimately.

Besides this, only extrapolating the future waste generation statistics based on a few factors may not be very accurate, but a holistic approach may improve the accuracy of waste generation statistics. Future waste management planning can only be done satisfactorily based on sound, quantitative data. Without such future preparations, a municipality may find themselves with inadequate resources and fail to effectively manage the accumulating waste. The complexity of future scenarios in waste management is exacerbated by the reduction in available landfill airspace and the inability of land to naturally assimilate the growing toxicity of waste products (Phiri, 2003). The impact of landfill airspace scarcity is acute in Europe and North America and has led to stringent environmental laws to conserve the existing space. In Europe and North America, communities are legally compelled to e.g compost putrescible waste as a measure to save the dwindling airspace at landfills (Curzio et al., 1994). The population is increasing at an exponential rate leading to significant increases in waste

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Abbreviations: DEAT, Department of environmental affairs and tourism; **MSW,** municipal solid Waste**; DWAF,** department of water affairs and forestry; **GDP,** gross domestic product, **EU,** European Union.

generation, while resource depletion is growing and replenishment is extremely low. Such a scenario can be helped by a wise economic use of present resources and an economic exploitation of future resources but needs substantiated planning. To be in control of such a complex situation the future scenario should at least be estimated and preparation of a sound solid waste management plan for the preferred applicable and feasible alternatives prepared.

Literature shows that the efficient management of waste varies between countries based on various economic factors (UNEP, 1996). Curzio et al. (1994) acknowledge that data on waste generation rates is scanty but there is consensus that the total quantity of waste produced is growing. The knowledge that the waste generation is increasing is a point of departure, but the knowledge of the estimated rate may lead to the formulation of better management techniques. In developing countries, the lack of technology and funds (Curzio et al., 1994; Holmes,1984) are some of the main constraints to dealing with waste, while in Europe and North America one of the main constraints is available land (UNEP, 1996). Such constraints can be best handled if the waste streams are accurately known and understood. It is advantageous for municipalities to have a way to approximate their current and future waste generation trends in order to plan and finance an efficient economic program of dealing with future waste streams. In South Africa, future quantities of waste in various municipalities are approximated based on the current waste received at landfills (Deat, 2000), but no comprehensive forecast of future waste generation and resource requirements, resulting often in poor service delivery, due to inadequate budgets and poor planning (Godfrey, 2006). Waste management data is unreliable or not available from some municipalities because of the inefficiency of municipalities in supplying it to the relevant authorities for planning purposes (Godfrey, 2006). Previously waste management resource allocations were based on pre-1994 data which were collected primarily on racial grounds and are now outdated and inapplicable (Qotole et al., 2001).

South African situation

Presently various municipalities fail to supply adequate waste management service to their communities (Godfrey, 2006; Deat, 2001). This is shown by the increase in uncollected waste in high density suburbs. In various places liter is scattered and also waste accumulates in non-designated places. One of the main causes of poor service in most of the municipalities is lack of proper planning although staff, equipment and poor access to certain places are also given as reasons (Godfrey, 2006). A survey which was done in 2003/2004 showed that about 60% of South African municipalities could not perform their waste management functions to standard, this with a budget in excess of R1.17 billion. For 2005/2006 the budget was increased by 24% to R1.45 million but with little improvement in the performance level (Godfrey, 2006). Based on the mentioned facts the failure was probably due to poor planning and budgeting of resources. The lack of resources or adequate resources is the obstacle both locally and internationally to waste management service delivery. With proper planning and increased budget it is possible not to adequately deliver if the budget is still below minimum required level. The increase could have been enough only to cover-up inflation. Coetzee (2006), reported that population growth and municipal service have not been matched by funding from National Treasury – average annual budget increases have been parameter–driven, and have approximated the rate of inflation (CPIX), while the service needs and growth in waste volumes, in line with economic growth and consumption, have exceeded the funding. The creation of this model was stimulated by the identification of the failures of the different municipalities in delivery of waste management services. This is coupled by the fact that waste streams which were identified as priority waste are still to be dealt with efficiently in many provinces and municipalities. In terms of the Municipality System Act (MSA) (Act 32 of 2000), waste management is a basic municipal service, but has seldom received enough priority and funding: this will further impact on implementing preventative and enforcement measures that will divert sufficient waste from landfills. According to Oelofse (2006), the national government allocates the annual budget three years in advance and therefore this model can be applicable within this time scale (Coetzee, 20006).

Future waste quantities

In support of the Polokwane declaration, a way of estimating recycling rate to achieve the set target is examined. The report incorporates the projection of population, waste projection, waste management budget and the determination of expected recycling rates to ensure that less than 50% waste reaches the landfills by 2012. Control of waste quantities through minimization, recovery, avoidance, recycling, reuse and policies implementation is basic suggested ways to achieve the set targets. Knowledge of the approximate future waste quantities being generated and the subsequent resources required in dealing with those volumes is the basis on which precautionary measures can be taken to avoid aspects such as under budgeting. Successful waste generation prediction and associated planning may lead to the implementation of appropriate, alternative, cheaper technologies in waste management currents situations. The formulation of projections can be done based on knowledge and assumptions of the future economic, social, environmental, technological, institutional and political environment. From this the strategy which best fits the available resources for a cost effective and appropriate future waste management system can be evaluated. Based on the above mentioned factors the future scenarios can be estimated although with limited accuracy due to the dynamics of present and future environments.To formulate strategies for waste management, a quantitative understanding of the waste streams is necessary (Deat, 2005). Anticipated changes in population growth, development and economic growth are some of the indicators on which waste generation forecasts can be based. Often previous waste generation trends are used in projecting future waste volumes, associated waste management resources or budget. However this assumes that the historical trend in waste generation will be contained into the future. The budget may include labour costs, equipment costs, research and development costs and other associated costs.

Other projections

Future scenarios have been projected with various degrees of accuracy in various countries (Eurostat, 2000) by various organizations. The ultimate reason was to use the information in preparation of future environment. Various countries have projected expected future waste volumes, expenditure, economic developments and the like and this has helped them in partially gaining control of the future environmental trends. Throughout the world, projections for different period length are done in various aspects and the following are some of the ongoing projections:

(1) New Zealand - Will present their first projection report in June 2006; (Brown et al., 2006).
(2) Norway - Special report in 2004 with projections up to 2060; (Brown et al., 2006).
(3) European Union - European Commission and Economic Policy Committee's report in February 2006 gives projections up to 2050; (Brown et al, 2006).
(4) Germany - First report in June 2005 gives projections to 2050; (Brown et al., 2006).
(5) Australia - Productivity Commission Research Report gives projections to 2044-45; (Brown et al., 2006).
(6) United States - 75-year projection in the yearly budget proposal; (Brown et al., 2006).
(7) United Kingdom - 50-year projection included in the yearly pre-budget documents in December; (Brown et al., 2006).

Local Authority Waste Recycling Recovery and Disposal (LAWRRD) decision support tool designed to provide means of evaluating policy options for municipal solid waste management in England (Brown et al., 2006). One of the most comprehensive works was done by the environmental protection department of Hong Kong in 1998 (Environmental Protection Department, 1998). In the work the following aspects were evaluated; correlation of quantity of Municipal Solid Waste (MSW) with Gross Domestic Product (GDP), MSW projection and forecast of construction and demolition waste. In the work, they took into consideration population, economic activities and domestic waste quantity which are also considered in the model under suggestion.

INDICATORS OF WASTE GENERATION

Gross domestic product (GDP) and gross geograhyic product (GGP)

Waste volumes and types are an indirect indicator of the country or community's income and economic development level (NAPUWM, 2007). Based on this the GDP and population growth can justifiably be included in the waste projection model. However it seems to be a duplication to use both factors as both show positive correlation in waste generation quantity. In the Cape Town waste projection model (City of Cape Town IWPM, 2004) it was discovered that population projection had a closer correlation with waste volumes than with GDP. In analyzing the waste generation trends for Hong Kong, the environmental protection department, found that there is a close relationship between population and domestic waste quantity, and between economic development (GDP) and municipal solid waste quantity (Figure 1) (EPD, 1998). As country's production increases, so the GDP rises and the subsequent waste volumes, as demonstrated in Figure 1. While no such information exists for South Africa, the above correlation is expected to hold true.

Similar trends were also reported the European Union (EU) in 1995 (Euro, 1995). On the basis of the Eurostat figures, waste generation in the EU was seen to increase in the year 1995 with increasing GDP as shown in the Figure 2. In the manufacturing sector, waste quantities are influenced by the efficiency in resource use in production and by the quantities of goods produced and consumed. Based on such an understanding, as the country's economic growth increases the waste volumes inevitably increase and hence the positive correlation between the GDP and the waste generation. Such a deduction was reached while analyzing the OECD waste generation statistics whereby it was found that the GDP grew by 6.5% and the waste generation grew by 10% in Organization for Economic Co-operation and Development (OECD) Europe (Eurostat, 2000). According to AAAS (2006), there is correlation between community affluence and waste generation as was identified in OECD. A 40 percent increase in the GDP of countries belonging to the OECD since 1980 has been

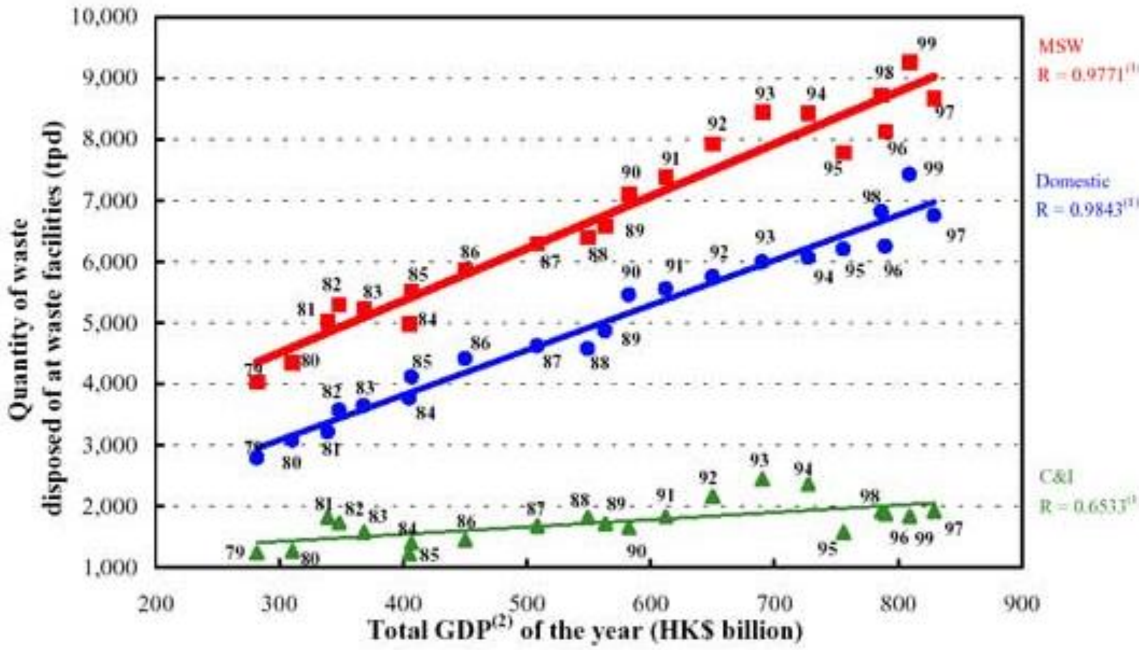


Figure 1. Correlation between GDP and waste generation (from EPD, 2006).

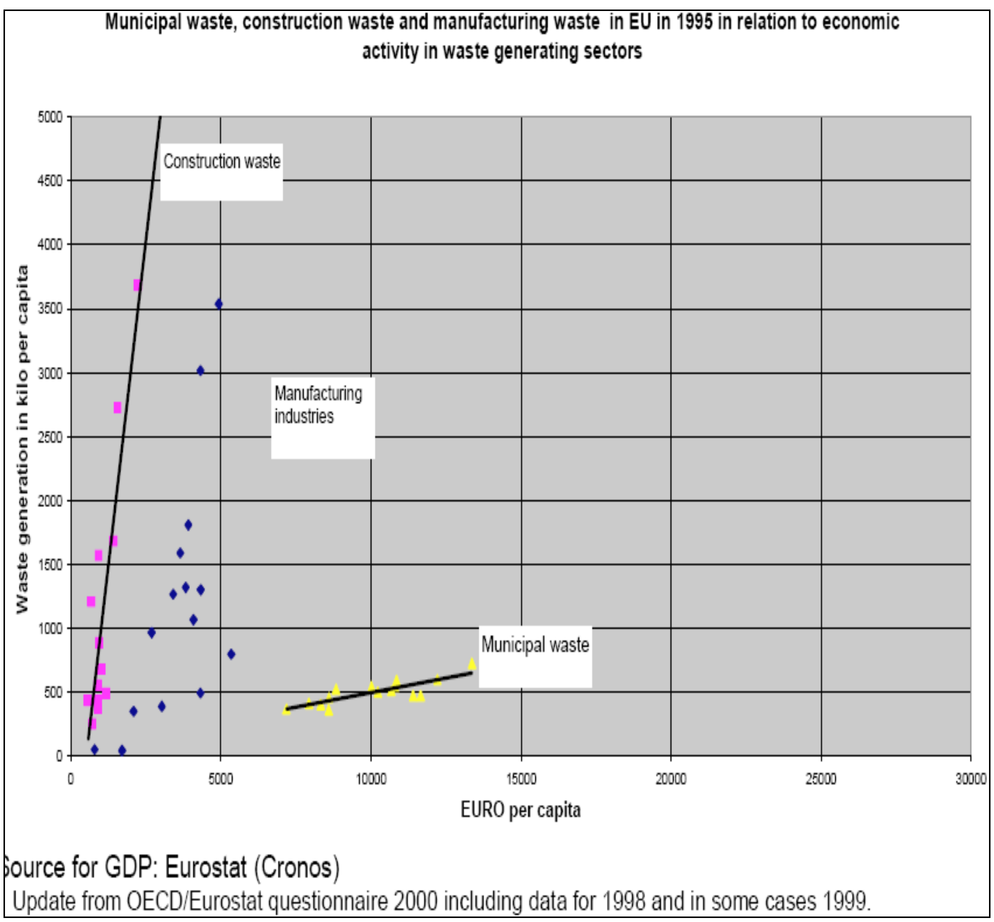


Figure 2. Correlation between GDP and waste generation (Eurostat, 2000).

accompanied by the same percentage growth in municipal waste. The OECD predicts that there will be a further 70 to 100 percent increase in GDP in its region by 2020 (AAAS, 2007).

Research on the City of Cape Town waste generation trends revealed that between 1996 and 2001 the population increased by 1.57% while the waste quantity increased by 3.8% (City of Cape Town IWPM, 2004). This is a common phenomenon in South Africa which is currently seeing increased levels of urbanization and affluence (per com, Godfrey, 2007). The waste quantity generation rate actually doubled the population increase rate. However during the same period the Gross Geographic Product (GGP) ranged between 2.6 - 3% (Deventer, 2002). It seems GGP is more accurate and almost proportional to the rate of increase of waste and therefore can be regarded as an accurate predictor of waste generation trends.

Income levels

On the other side income also indicates the potential waste generation per capita in a society. Usually the higher the income level the higher the waste generation per capita, and the lower the income level the lower the waste generation per capita. Countries such as China, the United States of America and some in Europe have the highest waste generation per capita, while the generation rates for low income countries average only 0.4-0.6 kg/person/day and industrialized countries rate at 0.7-1.8 kg/person/day (Zerbock, 2003). This is typically due to differing consumer patterns between the rich and poor. The affluent communities tend to feed on processed foods with high packaging content and do not repair worn out gadgets while the poor feed on unrefined foods and typical reuse packaging materials e.g. paper and cardboard for fuel and generate fewer residues. Since the poor often cannot afford new appliances these communities mainly repair old appliances for reuse (Ogawa, 2005) which generally decreases the waste generation. Waste generation rates reflect the economic status of the society; the more affluent the society the high the waste produced per capita (Gauteng State of Environment, 2006). Technological advancements, combined with population growth, increases the volume of waste generated in urban areas significantly, as a result the need for sustainable waste management service and facilities inherently increases. To deal with this waste increase, adequate financial resources and strategies are required and the know-how on how to finance the waste management processes is of great importance.

Based on discussed facts the knowledge of estimated future waste quantities and budget is important. While often of lower than required accuracy, forecasts are helpful in the allocation of resources. The future scenarios can be extrapolated from previous known facts and trends. According to DEAT (2000), locally there are three basic techniques used to estimate waste quantities. These are modeling techniques, physical sampling and direct techniques. The future waste trends, that is, quantities, qualities and characteristics of waste may be estimated using the information collected on the domestic waste generation rates per capita for each socio-economic category, the population, population distribution and commercial and industrial generation rates (DEAT, 2000). Although this is basically applicable, its accuracy is probably limited since it does not consider recycling targets which will be considered in the model to be developed. One target which was set by DEAT is the Polokwane declaration of stabilizing waste generation and reduce disposal by 50% by 2012 and develop a plan for zero waste by 2022.

Other possible considerations

The following are some of the aspects which can be considered for inclusion in a more comprehensive model. These are South Africa performance in business investment, foreign direct inward investment (FDI), Research and development, E-commerce, and International trade. While noted, these factors are not currently included in the first model, a model instead aimed at approximating the generation of waste for scenario planning. With the current limitations in data availability and quality a more comprehensive model; may at this stage provide more certain answers as opposed to simple, basic model. It is also believed that the intended use of the model will dictate the other aspects to include in a basic model design. In other words this model supplies the base on which to tailor-make the other models in relation to their sphere of application. Above mentioned aspects will not be considered at this level of the model. It however should be mentioned that the improvement of South Africa in participation and share in international market increases the country's GDP which impacts on the waste per capita generation. At the same time the research and development can increase the country's economy, hence affluence and also increasing the waste per capita.

Waste generation

Waste can be classified according to a number of criteria, such as its origin, toxicity, collection and re-use. In projecting future waste generation the inconsistencies in some waste streams, sudden surges and unplanned developments may cause inaccuracies. Due to such problems the different waste classes will be dealt with separately in a more detailed model. As previously noted, there may arise a situation whereby the projections are to

Table 1. Waste generation in selected countries (kg/capita/annum).

Country	Waste generation (kg/capita/a)
Austria	560
France	510
Russia	340
U.K	560
Israel	700

Table 2. Waste generation in different provinces of South Africa (1996).

Province	General waste (m^3/a)	Percentage per province (%)	Population (1996 Census)	Per capita waste generation
Mpumalanga	3,831,000	9.1	2,800,711	1.37
Eastern Cape	2,281,000	5.4	6,302,525	0.36
Free State	1,675,000	4.0	2,633,504	0.64
Gauteng	17,899,000	42.4	7,348,423	2.44
KwaZulu-Natal	4,174,000	9.9	8,417,021	0.50
North West	1,625,000	3.8	3,354,825	0.48
Northern Cape	733,000	1.7	840,321	0.87
Nnorther	1,470,000	3.5	4,929,368	0.30
Western Cape	8,543,000	20.2	3,956,875	2.16
Total	42,230,000	100	40,583,573	1.04

(Total costs are associated with waste management (DWAF, 1998; Stats SA, 2002).

be done based on certain criterion and that may warrant changing or improvising the model to suite such a situation.

Municipal solid waste

In this report there are waste types which are influenced mainly by population increase, GDP and other usual activities. MSW generation will be mainly focused on, because it is produced at households and influenced by economic activities. The assumption is made that MSW generation is influenced by GDP, waste generation rates (per capita generation) and population. It is therefore logical to project these waste volumes based on the three aspects, but in this report to reduce duplication and complication the waste per capita, population growth and population would be considered.

Gauteng produces the highest volume of waste in South Africa, with the per capita waste generation of 2.44 m^3/capita/annum (DEAT, 1998), shown in table 2.This shows how affluent Gauteng is in comparison to the other provinces. It is due to commercial, business and industrial development contributing to waste disposal to landfills. Table 1 shows waste generation rates in other countries. The Gauteng preliminary SoER indicates waste generation from households requiring collection and disposal in Gauteng to be 1.46 kg/capita/annum in 1996, with a population growth rate of 2% (Statistics S.A., 2001). Waste generation average has grown to 187 kg/capita/annum in 2003 with an associated population growth rate of 3.1 to 4%, considered to the present population growth rate.

Waste separation and recycling

The DEAT (2005) identified priority waste streams. These are waste streams which are being recycled and still hold significant potential for optimization and increase recycling, or waste which is not currently recycled to a significant degree, but which holds significant potential for recycling (DEAT, 2005). The knowledge of present waste recycling capacity and potential in other waste identified as priority together may form the basis of setting total realistic recycling targets.

A holistic integrated approach as documented in the White Paper on Integrated Pollution and Waste Management (IP and WM) shows that the National Waste Management Strategy has shifted from an “end-of-pipe” approach to one of prevention and reduction of waste generation (DEAT, 1999a). Such an understanding requires monitoring tools of present success in prevention and reduction and upon it realistic future targets can be set or adjusted to suit the resource and technology capacity and capability. In line with the waste projection approach ideas and national priorities, the model seeks to include the aspect of all recyclable waste in the future scenario modeling. The knowledge of recycling potential of different priority waste streams and total expected recycling targets may also improve the applicability of the proposed model since it will increase the accuracy in projection of future waste volumes and associated costs.

In any society the rate of waste generation is expected to increase significantly if the prevention, separation and recycling measures are not in place especially in a growing economy like South Africa. With efficient prevention, separation at source and recycling the solid waste volumes reaching landfills are expected to decrease. Exceptional situations may call for stringent landfill design increasing the operation costs but as long as other waste recycling measures are in place, the costs may not significantly impact on the total budget. A sustainable approach may include an investment in educating the community on the issues of waste management prompting them to start recycling activities at their homes. If separation at source is practiced, municipal revenue may be saved which was meant to manage waste at landfills by the municipality. Waste recycling practices such as composting leads to landfill airspace savings, new resource creation, and economic gains from compost sales as well as reduction in transport costs.

Aspects of waste management and expenses

Several activities are responsible for the high waste management costs incurred by municipalities. Some of these activities are incurred once off in a financial year, some multiple and others are regularly incurred. The total expenses which are incurred by municipalities include: Administration, waste collection, litter prevention and control, public place and event recycling, industry waste avoidance and resource recovery, commercial/institutional waste avoidance and resource recovery, food organic recovery, green organic recovery, resource recovery and waste management facilities, household chemicals collection, community and school education, communication and information, data collection and grants. DEAT (2005), list the following expenses: personal wages, transport, operating and maintenance, administration and staffing, environmental impact abatement and penalties and interests and depreciation. However in this model all the aspects of waste management are considered together as a package and fall under waste management budget.

MATERIALS AND METHODS

Scope of work

This report focuses on the formulation of a simple model for projecting the generation of future quantities of municipal solid waste (MSW) and the associated waste management resource requirements. The City of Johannesburg in the Gauteng Province was selected as a case study to evaluate the models applicability. Gauteng Province was chosen principally because of the availability of suitable data. While tested and calibrated at municipal level, the model is expected to also be suitable for waste generation prediction at regional, provincial or national level.

Objectives

The objectives of this report are to:

(i) Identify indicators of waste generation and rate.
(ii) Suggest an approach to link waste generation indicators to social and economic indicators
(iii) Provide a mathematical formula to project waste generation quantities.
(iv) Suggest waste recycling rate to achieve the set target.
(v) Suggest approximate budget requirements based on the predicted quantities.
(vi) Suggest applicability conditions for the proposed model.

As delimitation measures the report focuses on municipal solid waste only because it is the waste sector produced by households and commerce which have discernible trends associated with population dynamics, and for which municipalities are constitutionally responsible (DEAT, 2005). Other forms of waste which are catered for by generators e.g industrial or health care risk waste are not considered here since the focus of this report is on the assessment of municipal resource requirements.

For the sake of simplicity, consistency and continuity the model will be developed in line with the Department of Environmental Affairs and Tourism (DEAT) approach to the projection of future waste quantities (DEAT, 2000). The idea being to determine the quantity of waste generated which is likely to be disposed off at municipal landfills in the future, and the resources required to

Table 3. Illustration of the recycling target impact on waste volumes.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Percentage target reduction in waste to landfill (%)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Waste quantity (Million Kg)	1.7	1.6	1.5	1.4	1.3	1.2	1.2	1.1	1.0	1.0	0.9

manage this waste. Recycling targets and the effect of recycling on waste generation and disposal are also put into perspective.

MODEL: Waste volume and expenditure model (WVEM)

Aspects of the model

Waste volume

The basic waste quantities are a function of population, waste generation per capita and the waste reduction target. The EPA (1998) found that there was a close correlation between population and MSW waste quantity. The increase in population subsequently leads to increase in total waste volume, but the waste per capita can only increase as a result of the country's economic growth represented as the GDP. The recycling target has the effect of reducing the quantity of waste to be disposed off and therefore the total volume of waste to be managed at landfill is reduced.

Waste volume = f (waste per capita, GDP, population, recycling target)……………..(1)

Recycling targets

Recycling targets set the anticipated realistic goals to be achieved by the municipality through technology implementation, policies, legislation and other tools. In Hong Kong (1998), a reduction level of MSW for the future years 2001, 2003, 2005 and 2007 was set in 1998 as 10%, 14%, 22% and 40% respectively by the Waste Reduction Framework Plan which was launched in November 1998 (EPA, 1998). Japan has been very successful in reducing the MSW. Japan set very high recycling targets by instituting the 1991 Law concerning the growth of the use of recycling resources (Green Plans, 1993). The objective of the targets was to act as guide lines in policy implementation and be able to gauge achievement in given period and consequently reduce waste to landfill. In South Africa the Polokwane declaration (DEAT, 2005) will be referred to in this work and its effect on future waste generation analyzed. It is a target aimed at stabilizing waste generation and reducing waste disposal to landfill by 50% by 2012 and develop a plan zero waste by 2022. If the Polokwane Declaration was to be successfully implemented and assuming a linear implementation, waste volumes going to the landfills will be gradually reduced annually as shown in the Table 3. It is calculated by:

Waste quantity = Wi Qi = n * x *(1 + p/100)i-1(1 – q/100) i-1 … (2)

Whereby n-waste quantity in 2001, x - Population in 2001, waste quantity in year i, Wi - waste quantity in year i, Qi – population in year i, p – Population growth rate and q – Waste growth rate.

From year 2002 to 2012 it is expected that the waste reduction momentum gradually increase as shown in Table 3, as the waste to landfill reduces also gradually. Since it is a national goal, it is assumed that the impact will be the same in all municipalities and provinces. Precisely if the recycling targets are adhered to, waste disposal would be reduced by 50% by year 2012 (Ball, 2005). The impact of recycling targets on waste management is to reduce future waste volumes, but subsequent targets should be seen to be attainable. Implementation of composting of organic waste from the MSW stream, for example estimated to be between 10 - 40% (DEAT, 2005) of MSW in South Africa, can result in considerable reductions in waste to landfill. In a parallel waste generation projection work carried out in Hong Kong by the Environmental Protection Department (1998), the waste reduction targets were taken into consideration in trying to establish the future waste volume to be managed.

Population

Population size is a function of several processes (migration, urbanization, disease etc) and some are shown in the formula. There is high migration into the cities as opposed to emigration resulting in a gradual increase in population and an increase in waste generation with associated lifestyle

Population = f (immigration, emigration, birth rate, etc) …………………(3)

The official population figures for South Africa which have been published based on all population aspects will be considered. Below shows the population and population growth rate from statistics (Statistics S.A) a credible source of data. In the absence of other credible sources the national figure in population increases can be used for Gauteng province. In Cape Town between 1996 and 2001 it was reported that the waste generation rate was double the population growth rate (City of Cape Town IWPM, 2004) and this can be considered in this report but only if several cases have such trends.

From the UNISA project (Van Aardt, 2006), various organization's forecasts of the South African population were compared and are shown in the Table 4 for comparison. The South African population forecast by different organizations shows no significant difference putting into consideration that population demography is very dynamic. These forecasts may have or may not have taken into consideration potential significant surges in population due to global events such as the World Cup hosting in South Africa in 2010 which may significantly change the population demography due to an influx of visitors. In China by including the present waste volumes and waste expenses, annual growth and average annual production the future waste expense was projected successfully (NAPUWM, 1999).

Table 4. South African population forecasts comparative table (van Aard, 2006).

Agency	2005	2010	2015	2020
HSRC	45 070 000	46 090 000	46 020 000	47 460 000
U.S Census Bureau	42 550 000	40 610 000	38 040 000	35 850 000
World Bank	43 980 000	44 780 000	45 820 000	47 020 000
Dorrington et al	47 485 369	47 392 050	-	-
BMR –CvA	47 004 745	47 958 250	48 984 542	50 561 158
United nations MV	45 010 000	45 140 000	44 616 000	43 977 000
CIA- UN	-	49 169 000	42 969 000	57 062 000
MEAN	45 183 352	45 877 044	46 224 924	46 988 360

Waste management expense or budget

From present waste volumes, population, GDP, recycling targets the future waste expenses can project, the previous trends as a point of departure. Waste management expenses = f (GDP, present and future waste expenses, population). It is however not appropriate to include inflation at the expenses calculation but can be included after the expenses have been evaluated. Inflation is not a direct influence of waste generation but only impacts on the present or future expenses. In this work the waste management expenses is a product of waste quantity and cost per quantity.

Gross domestic product (GDP) and gross provincial product (GPP)

As previously mentioned the GDP and GPP reflect quality of life of the country or province. The figures also show the economic development level of the country due to economic activities. Economic growth, or growth in production and consumption, is the key driving force behind the escalating waste volumes. Larger homes, higher housing standards, frequent decoration and reconstruction and increased spending on furniture and household appliances are typical examples of how affluence generates waste. The affluent the community the higher the GDP, and the higher waste generation per capita. In 1995 to 2002 Gauteng had a GPP of 3.3% which was higher than the national GDP of 2.7%. Johannesburg has GPP of 3.1%. This means generally Gauteng was more economically developing than the whole country on average.

THE PROPOSED MODEL

EPA (1998) used a relatively simple and straight way of projecting future waste volume needing disposal. EPA used an approach of multiplying the projected waste generation rate per capita with predicted population or number of employees. In this approach domestic waste was calculated separately and commercial and industrial waste separately and then added together to get the total expected waste generated. The model did not take into consideration the country recycling targets.

The suggested model was formulated based on those lines but with a slight different approach. In a bid to explain the formulated model (WVEM) by the author, only five aspects were considered that is, population growth rate, waste generation rate, and recycling target, waste per capita and population, but this does not mean that there are the only aspects which can considered. The aspects give indirect information on the waste volume and waste volume increase and therefore give a picture of the future resource requirements for waste management. In this report several assumptions were suggested and are listed below.

Assumptions

(i) It was assumed the increase in population is directly related to the increase in total waste volume. In other words there is linear relationship between waste volume increase and population increase.
(ii) It is also assumed that the country characteristics are homogeneous if applied at national level but at provincial or municipality level relevant data is used.
(iii) It is assumed the GDP of the country is the same as for Gauteng.
General waste trends are same throughout the country when applied to national level.

The various figures used are also not correspondingly for the same year, but for illustration's sack were used if no actual same year data is available. The formula shows that total waste volume is a function of population size, recycling targets, and GDP (3.3%, and 1995 to 2002), 3.1% for 1996 to 2004 (Statistics S.A, 2000), for 2003, 2004, 2005 and 2006 is 3.1, 4.8, 5.1 and 5 respectively (Fact sheet 4), and Doing business has also 2.7, 3.6 , 2.8 , 3.7, and 4.3 for years 2001, 2002, 2003, 2004 and 2005 respectively. Such different figures from different sources bring confusion to the user but Statistics S.A as source is considered to be more credible and therefore shall be often quoted.

The formula: Waste quantity

$$E = EO (1- q/100) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Whereby E – present waste quantity,
EO - Waste quantity in 2001
q - Recycling rate

The formula: Waste budget

Waste budget = (Population projected *Budget per capita) * Inflation

$$F= (E*J) * [(D\backslash 100) +1) \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

E-projectet waste quantity, X - Population, F – projected waste budget or B - waste per capita
Finance, D –Inflation rate, C – Recycling target, J – Budget per capita.

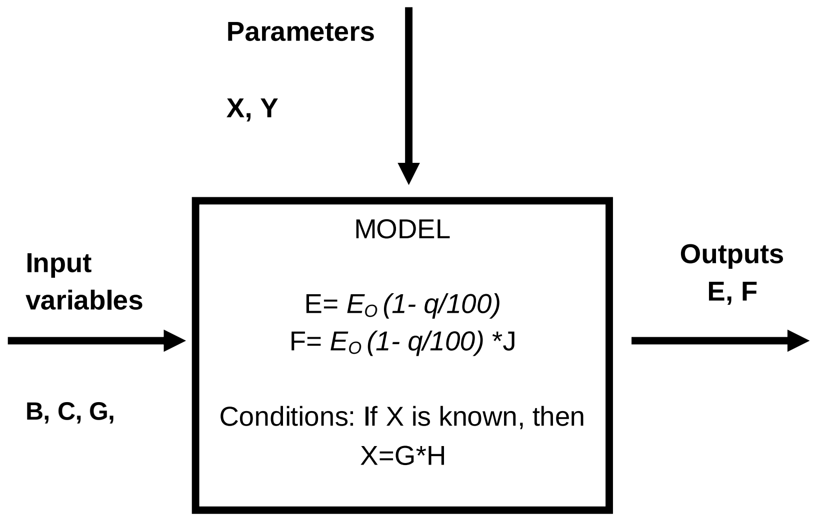


Figure 3. Schematic representation of the model**.** Where: A – GDP % increase; B – Population growth rate %; C – % Y – Budget per capita H – Waste per capita Recycling target; D – Inflation; E – Projected waste volume; F – Projected future budget; G – Population; X – Current population; J – Budget per Kg; K – Starting budget.

The model may be depicted diagrammatically as indicated in Figure 3. The illustration shows that the possible input variables which are GDP or PDP, population growth, percentage recycling targets etc are fed into the system which has more stable parameters such as the current waste volume and per capita budget. The outputs are the projected waste volumes and projected future budget which are critical in planning.

CASE STUDY: CITY OF JOHANNESBURG

In this report two case studies are examined: city of Johannesburg metropolitan municipality and South Africa.

Overview

The city of Johannesburg spends about R170 million (Venter, 2006) to clean the city. The dirty environment is a result of various interacting factors. People's attitudes, lack of environmental understanding, unwillingness to pay for service are some of the causes of a poor living environment. From the Municipality's side reasons includes poor planning, poor monitoring and lack of enforcement. It is statistically robust to make forward projections for twenty years or so, on the basis of even ten years' data (information sheet 8, 2006). Short-term predictions are likely to be more accurate than long term ones because the short term periods are unlikely to be significantly affected by various massive economic activities.

In a report which was written by Qotole et al. (n.d), they presented the allocation of waste management per capital (Table 1). Figures were given if available and omitted if no concrete figures are available. The table shows the discriminatory allocation of resources to different communities predominantly based on racial grounds. Under such conditions where resources are allocated per person it is relatively easy to forecast future waste management resources needed through the population forecasting, but its accuracy and applicability is questionable. To ignore GDP, population increase, waste reduction target and recycling rate is illogical in waste volume and resource forecasts. The average budget per person is R87 per annum and from the 2.44 m^3 per year, the cost per cubic meter is R35.65/cubic meter per annum. Source: Author's elaboration from GJMC population statistics and 1999 to 2001 Budget. In the work by Qotole et al (n.d) it is not explained how they came to these budget allocation figures which could be either by dividing the number of people with the total budget or by just obtaining the estimated per capita budget figures from the municipality authorities.

Validation of the model

For model validation the actual data from the past is compared to the projected values or values calculated by use of the model in this report. For Johannesburg it was given that the city produced a quantity of waste of 1 629 620 172 tones in 2000 at 10% recycling rate. The waste generation per person per annum was given as 584Kg/p/annum (City of Johannesburg, 2001) and the population at 3 100 495. The GDP was fixed at 2% until 2020 although it changed insignificantly annually. From such actual data the total waste quantity was found to be 1 629 620 172 tones for year 2000.The data for the subsequent years is given in the table (column 6). By changing the recycling target in the model to determine the waste quantity of the same size as original it was found that the recycling rate of 4.5% gives approximately the same waste quantity as the actual data shown in column 8. The deviation is approximately 0.05% which is almost and insignificant and therefore shows how accurate is the model in projecting future waste quantities.

As depicted by the graphs, at zero recycling rate the total waste quantity increase gradually and reaches maximum and gradually reduces after 2014 due to population decrease, due to some natural disasters such as diseases. At recycling rate of 5% the waste volumes reduces as shown very steeply but less than at 50% recycling rate. At 50% recycling rate the waste quantity reduces

Table 5. Allocation of resources for waste management in Johannesburg (Unicity, 2000).

Region	Population	Staff: Residents ratio	Budget: Resident ratio (R per person per annum)
Diepsloot	45 000	1:228	n/a
Midrand/Ivory Park	500 000	n/a	n/a
Sandton/Rosebank	208 000	1:941	100
Northcliff	216 000	1:977	90
Roodeport	225 000	1:709	115
Doornkop/Soweto	1 100 000 (combined with Diepkloof/Meadowlands)	1:1,450	54
Alexandra	395 000	1:1,204	58
Inner City	180 000	1:549	128
Johannesburg South	200 000	1:610	115
Diepkloof/Meadowlands	See Doornkop/Soweto	1:2,000	31
Ennerdale/Orange Farm	270 000	1:2,842	n/a

very steeply as shown in the Figure 5. By implementation of the model it can be determined the rate at which to reduce waste to landfill to reach a certain target waste quantity or what target can be set to end up with a certain waste quantity. From it the waste expenses can be determined as previously demonstrated.

Application of the model

Several interacting factors influence waste generation and some are country specific. Some of the factors are not discernible and are difficult to account for. In this work the population size and growth rate, GDP or PDP and waste per capita are considered as the main influences of determining waste volumes and are discernible. The GDP reflects directly the social and economic development level, and presents indirectly the social and economic development level. It also presents indirectly the living standard of the citizens (3rd International Report, s.a). Population growth rate is a function of immigration, emigration, mortality but for the sack of simplification the Gauteng population growth which includes all the necessary factors will be used in this report and it's 4%.The Provincial gross domestic product of 3.1% for 1996 to 2004 (Stats .S.A, 2001) is used.

Input data

Population and population increase

The population size used in this work is the 2006 figure of 3 225 815 with population growth of 4% per annum (Statistics S.A, 2001). According to the model a constant population increases of 4% is used, but in reality it's expected to either increase of decrease but insignificantly. In using the model it is expected to make use of the updated population data.

GDP impact

The City of Johannesburg reports that the GDP or economic development of 2% has been constant for over a decade (Business Plan, 2001, 2006). A small fluctuation of magnitude of 0.1% is said to happen. Based on such information, for the model the yearly GDP has been taken as 2%.

Recycling targets

In recognition of the Polokwane declaration the aspect of recycling target discussed fixes constant rates each year. From 2001 to 2012 the expected total waste reduction is 50% and from 2001 it is 4.5% (Table 5).

Budget per capita

The Johannesburg average capita per head is used of R186 per capita per annum. This was calculated by dividing the starting budget of R700 000 000 by the population of 3225815 to get the budget per capita. The budget per capita is expected to plummet yearly as the waste volume reduces due to recycling activities.

RESULTS

Waste quantities

The general trends (Model data) in the projections show gradual reduction in waste volumes and subsequent reduction in the future waste budget needed. It is anticipated that if all measures are in place waste reduction targets would be reached.

Table 6. population figure found in dwaf (2006).

Date	October 2001	April 2006	Current annual growth (%)
Population	3225803	3753967	4

Table 7. Results of the projections by model WSEM.

Year	Population	Waste q percapita (kg/p/a)	Total waste generated (Kg)
2001	3,225,815	584	1,883,875,960
2002	3,354,848	584	1,959,230,998
2003	3,628,603	584	2,119,104,248
2004	4,081,685	584	2,383,704,081
2005	4,774,994	584	2,788,596,623
2006	5,809,511	584	3,392,754,175
2007	7,350,884	584	4,292,916,383
2008	9,673,262	584	5,649,185,094
2009	13,238,527	584	7,731,299,880
2010	18,842,552	584	11,004,050,444
2011	27,891,580	584	16,288,682,781
2012	42,937,806	584	25,075,678,780

Such trends are expected if there is strict adherence to policies and enforcement implemented to meet set targets. A graphical representation can be used to extrapolate further than 2012 or through relevant calculations. As an illustration the model was used changing the main five inputs, population growth, population (2001), waste per capita, recycling rate and target to see the impact on the waste production. The change of each input brings about the change in the waste quantities and expected budget. This is shown in the model.

In another Excel sheet there is a demonstration to illustrate using the GPP of 1.8%. From the graph the changes which can happen if the GPP is changed are on waste quantity and budget. Table 7 shows the created excel WVEM model. When the following figures are entered that is, input variables and calculated values at table is created further.

One of the most credible sources of data is Statistics S.A and as was found in the DWAF (2006) document, the following population figures are presented: The current population growth is assumed to be constant until 2012. If such a population growth is maintained then such predictions are realistic. In the (Annexure Tables 1 to 3) is the model through which the table was created. The data shown in the model can be changed, depending on the projection start date, the community characteristics and so forth.

Waste budget

Often the budget for communities, municipalities or provinces is done based on population size. That is to say budget is allocated per individual rather than on total waste quantity. Population traditionally increases exponential under normal circumstance, where there are no significant effects from natural disasters such as earth quakes and diseases like AIDS. However it should be noted that although the population may increase the waste to be disposed at landfill may be reducing due to government policies and general public practices. Table 7 shows the exponential increase in population and how the budget may be affected or change based on this. It is assumed the budget per capita is constant from year 2001 to 2012 although it is unlikely under normal circumstances Table 7 and Table 8 (Refer to Figure 7 for graph) shows the model validation by use of waste volumes at different recycling rates and Table 9 shows calculations to determine the exact recycling rate required to achieves set targets.

Scenarios

Depending on the target or objectives the rate of recycling can be set to achieve this. Different scenarios are examined in this report.

Effect of stabilizing land filling of waste

According to the Polokwane declaration the first objective is to stabilize the waste to landfill as interpreted in this report. In this report it implies the waste which was produced in 2001 at the Declaration time should be kept

Table 8. Relationship between the population increase and budget.

Year	Population	Budget per capita (Rands)	Total budget (Rands)
2001	3,225,815	87	280,645,905
2002	3,354,848	87	291,871,776
2003	3,628,603	87	315,688,461
2004	4,081,685	87	355,106,595
2005	4,774,994	87	415,424,478
2006	5,809,511	87	505,427,457
2007	7,350,884	87	639,526,908
2008	9,673,262	87	841,573,794
2009	13,238,527	87	1,151,751,849
2010	18,842,552	87	1,639,302,024
2011	27,891,580	87	2,426,567,460
2012	42,937,806	87	3,735,589,122

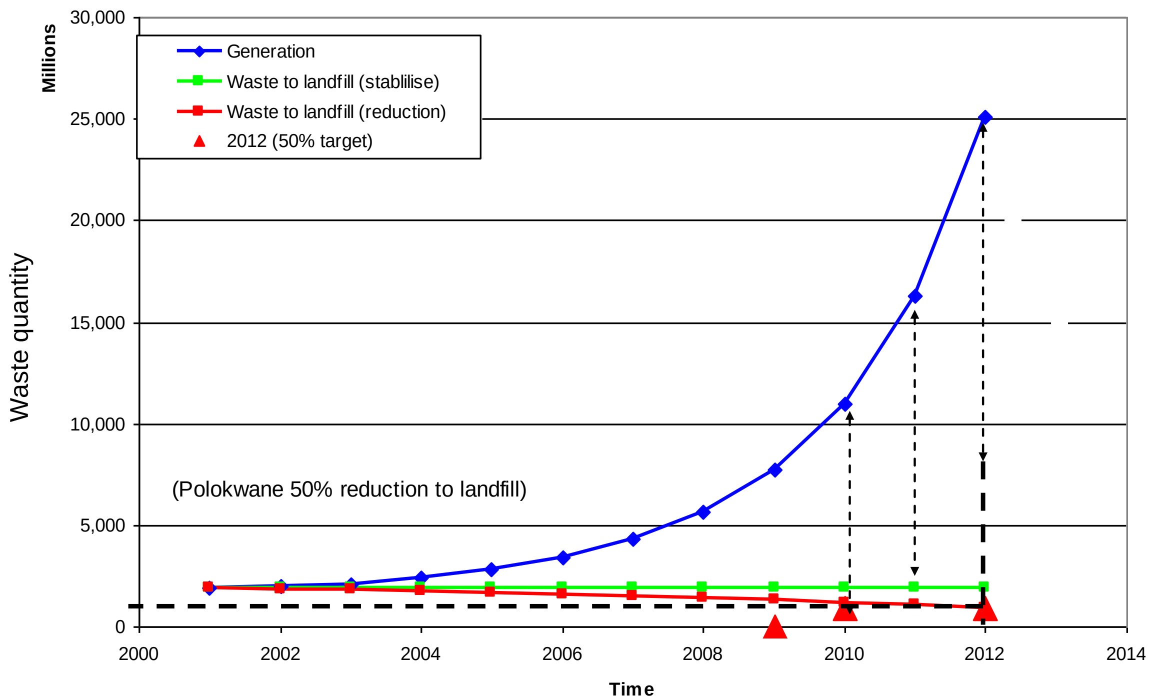


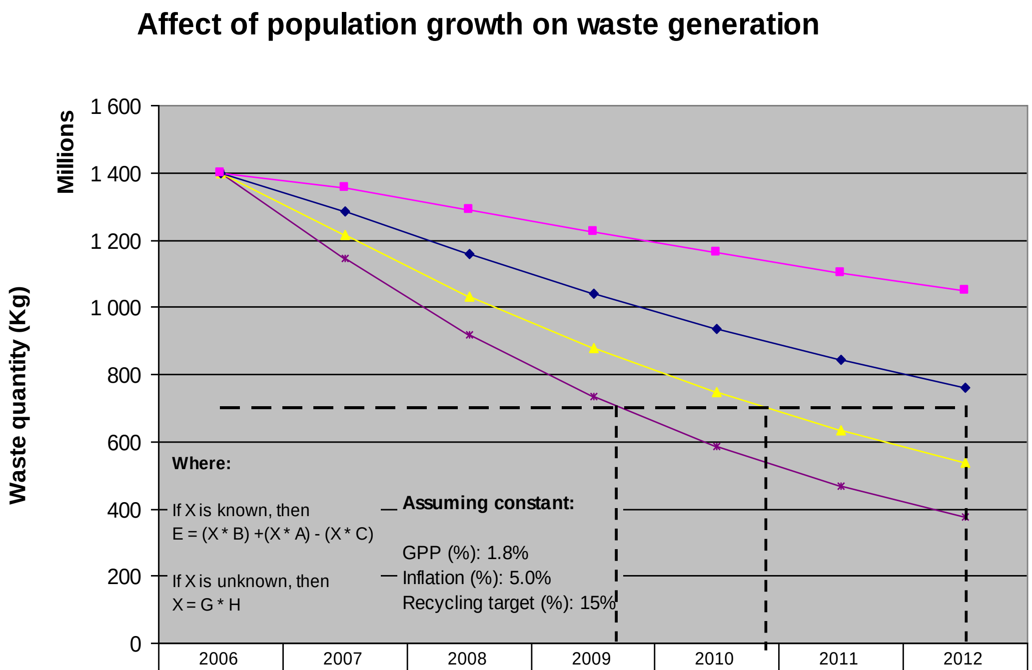
Figure 4. Waste quantity projection graph.

constant throughout to 2012. To achieve this, the rate of recycling should steadily increase to compensate the increase in population which influences waste quantity. As was determined (basic calculation approach in annexure) as shown in the last column of the model(Table 10), the recycling rate should increase from zero in 2001 to 92% in 2012 and the waste reaching the landfill is constant as shown in Figure 3. At a recycling rate increase of 2% of generation rate per annum, the compensation becomes almost 100% and that means the waste quantity will never increase from the 2001 quantity.

Column four shows the quantity of waste which is generated each and if there is no practice and policies like recycling, reuse and even cleaner technology the waste quantity would reach 25 075 678 780 kg by 2012. Such a status burdens the environment and budget, loss of resources, hazardous environment and the like.

Effect of recycling targets

Figure 4 shows the volume of waste which reaches the



	2006	2007	2008	2009	2010	2011	2012
Pop Growth -5%	1 400 000 000	1 145 200 000	916 160 000	732 928 000	586 342 400	469 073 920	375 259 136
Pop Growth 0%	1 400 000 000	1 215 200 000	1 032 920 000	877 982 000	746 284 700	634 341 995	539 190 696
Pop Growth 5%	1 400 000 000	1 285 200 000	1 156 680 000	1 041 012 000	936 910 800	843 219 720	758 897 748
Pop Growth 10%	1 400 000 000	1 355 200 000	1 287 440 000	1 223 068 000	1 161 914 600	1 103 818 870	1 048 627 927
Polokwane 2012	700 000 000	700 000 000	700 000 000	700 000 000	700 000 000	700 000 000	700 000 000

Time

Figure 5. The quantity of waste ending up at the landfill at different population growth rates.

landfill at GDP of 1.8% and population growth of 5% different recycling targets:

(i) At 4% rate a quantity of 959 523 million kg would be reaching the landfill by 2012.
(ii) At 15% rate a quantity of 758897 million kg would be reaching the landfill by 2012.
(iii) At 20% rate a quantity of 539190 million kg would be reaching the landfill by 2012.
(iv) At 0% rate a quantity of 1908296 million kg would be reaching the landfill by 2012.

Effect of population growth

Figure 5 shows the volume of waste which reaches the landfill at GDP of 1.8% and recycling target of 15% and different population growth rates:

(i) At 10% rate a quantity of 1048627 million kg would be reaching the landfill by 2012.
(ii) At 5% rate a quantity of 758897748 million kg would be reaching the landfill by 2012.
(iii) At 20% rate a quantity of 539190696 million kg would be reaching the landfill by 2012.
(iv) At 5% rate a quantity of 375 259136 million kg would be reaching the landfill by 2012.

CASE STUDY 2: SOUTH AFRICA

Overview

South Africa is a comparatively large country which fits both third world and first world status. Infrastructure and economic developments wise it matches the first world but lacks in other few aspects such as large income gap which resemble third world countries. It is approximated to have a population of around 47 million people unevenly distributed in the provinces. The population is highly concentrated in the Gauteng province which is the second smallest province (Table 11).

South Africa has an average population growth of 4% (Van Aard, 2006), but according to HSRC its 0.44% (HSRC, 2005). The population and projection of South Africa population is shown in Table 4. If South Africa has to practically achieve the recycling target set by Polokwane Declaration it has to recycle waste at a rate of 4.5% putting into assumption that this started in 2001 nationwide. Figure 6 shows the geographical location of

Figure 6. Map of South Africa (Africa: South Africa, S.A).

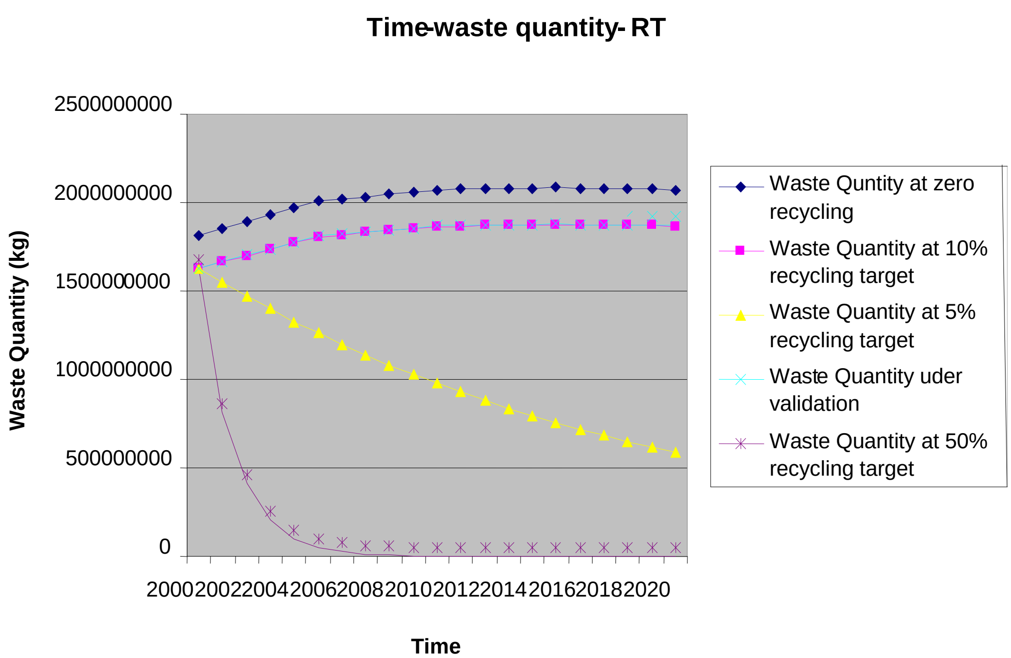


Figure 7. The quantity of waste ending up at the landfill at different recycling targets.

Table 9. The model validation by use of waste volumes at different recycling rates.

Year	Population	Budget per capita annually [R]	Waste per capita	Zero waste recycling	Actual waste at 10% recycling rate	Total waste at 5% Recycling target	Projected waste (kg)	Recycling target 50%
2000	3 100 495	87.0	584.0	1 810 689 080	1 629 620 172	1 629 620 172	1 629 620 172	1 629 620 172
2001	3 167 605	87.0	584.0	1 849 881 320	1 664 893 188	1 548 139 163	1 667 621 763	814 810 086
2002	3 234 715	87.0	584.0	1 889 073 560	1 700 166 204	1 470 732 205	1 702 952 588	407 405 043
2003	3 301 825	87.0	584.0	1 928 265 800	1 735 439 220	1 397 195 595	1 738 283 412	203 702 522
2004	3 368 935	87.0	584.0	1 967 458 040	1 770 712 236	1 327 335 815	1 773 614 237	101 851 261
2005	3 436 045	87.0	584.0	2 006 650 280	1 805 985 252	1 260 969 024	1 808 945 061	50 925 630
2006	3 458 683	87.0	584.0	2 019 870 872	1 817 883 785	1 197 920 573	1 820 863 094	25 462 815
2007	3 481 320	87.0	584.0	2 033 090 880	1 829 781 792	1 138 024 545	1 832 780 601	12 731 408
2008	3 503 958	87.0	584.0	2 046 311 472	1 841 680 325	1 081 123 317	1 844 698 634	6 365 704
2009	3 526 595	87.0	584.0	2 059 531 480	1 853 578 332	1 027 067 151	1 856 616 141	3 182 852
2010	3 549 233	87.0	584.0	2 072 752 072	1 865 476 865	975 713 794	1 868 534 174	1 591 426
2011	3 553 288	87.0	584.0	2 075 120 192	1 867 608 173	926 928 104	1 870 668 975	795 713
2012	3 557 343	87.0	584.0	2 077 488 312	1 869 739 481	880 581 699	1 872 803 776	397 856
2013	3 561 397	87.0	584.0	2 079 855 848	1 871 870 263	836 552 614	1 874 938 051	198 928
2014	3 565 452	87.0	584.0	2 082 223 968	1 874 001 571	794 724 983	1 877 072 852	99 464
2015	3 569 507	87.0	584.0	2 084 592 088	1 876 132 879	754 988 734	1 879 207 653	49 732
2016	3 565 397	87.0	584.0	2 082 191 848	1 873 972 663	717 239 297	1 877 043 896	24 866
2017	3 562 108	87.0	584.0	2 080 271 072	1 872 243 965	681 377 333	1 875 312 365	12 433
2018	3 558 820	87.0	584.0	2 078 350 880	1 870 515 792	647 308 466	1 873 581 360	6 217
2019	3 555 532	87.0	584.0	2 076 430 688	1 868 787 619	614 943 043	1 871 850 354	3 108
2020	3 548 955	87.0	584.0	2 072 589 720	1 865 330 748	584 195 891	1 868 387 818	1 554

(The accompanying table shows the impact of 2% recycling rate on the waste generation)

South Africa and its size.

DISCUSSION

DEAT intends making the waste tariff strategy a requirement for inclusion in the integrated waste management plans of local authorities (DEAT, 2006). The introduction and utilization of waste tariff strategy will assist local authorities with the basis for further use of economic tools for environmental sustainability of MSW services, such as instruments to encourage waste reduction, recycling and re-use or other environmental objectives (DEAT, 2006).

The suggested model serves as an economic tool in the estimation of the required budget for future waste management strategies. If included in the integrated waste management plans, the local authorities are expected to make sound economic waste management plans based on expected future waste trends.

Policies, legislation and targets are tools which can also be used to control waste volumes and waste expenditure. Set targets need to be supported by stringent legislation to be attainable. The country's recycling targets and policies may assist to reduce volumes of waste reaching landfills. The incorporation of all the mentioned aspects in the mathematical projection model may lead to a better estimation of future waste volumes and required resources. Problems of under-allocation or over-allocation of resources

Table 10. The model validation by use of waste volumes at different recycling rates.

Year	Population	Budget per capita annually [R]	Waste per capita	Zero waste recycling	Actual waste at 10% recycling rate	Total waste at 5% recycling target	Projected waste (kg)	Recycling target 50%
2000	3 100 495	87.0	584.0	1 810 689 080	1 629 620 172	1 629 620 172	1 629 620 172	1 629 620 172
2001	3 167 605	87.0	584.0	1 849 881 320	1 664 893 188	1 548 139 163	1 667 621 763	814 810 086
2002	3 234 715	87.0	584.0	1 889 073 560	1 700 166 204	1 470 732 205	1 702 952 588	407 405 043
2003	3 301 825	87.0	584.0	1 928 265 800	1 735 439 220	1 397 195 595	1 738 283 412	203 702 522
2004	3 368 935	87.0	584.0	1 967 458 040	1 770 712 236	1 327 335 815	1 773 614 237	101 851 261
2005	3 436 045	87.0	584.0	2 006 650 280	1 805 985 252	1 260 969 024	1 808 945 061	50 925 630
2006	3 458 683	87.0	584.0	2 019 870 872	1 817 883 785	1 197 920 573	1 820 863 094	25 462 815
2007	3 481 320	87.0	584.0	2 033 090 880	1 829 781 792	1 138 024 545	1 832 780 601	12 731 408
2008	3 503 958	87.0	584.0	2 046 311 472	1 841 680 325	1 081 123 317	1 844 698 634	6 365 704
2009	3 526 595	87.0	584.0	2 059 531 480	1 853 578 332	1 027 067 151	1 856 616 141	3 182 852
2010	3 549 233	87.0	584.0	2 072 752 072	1 865 476 865	975 713 794	1 868 534 174	1 591 426
2011	3 553 288	87.0	584.0	2 075 120 192	1 867 608 173	926 928 104	1 870 668 975	795 713
2012	3 557 343	87.0	584.0	2 077 488 312	1 869 739 481	880 581 699	1 872 803 776	397 856
2013	3 561 397	87.0	584.0	2 079 855 848	1 871 870 263	836 552 614	1 874 938 051	198 928
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2018	3 558 820	87.0	584.0	2 078 350 880	1 870 515 792	647 308 466	1 873 581 360	6 217
2019	3 555 532	87.0	584.0	2 076 430 688	1 868 787 619	614 943 043	1 871 850 354	3 108
2020	3 548 955	87.0	584.0	2 072 589 720	1 865 330 748	584 195 891	1 868 387 818	1 554

(The accompanying table shows the impact of 2% recycling rate on the waste generation).

can possibly be avoided if the model is properly implemented based on realistic goals. However at this stage of research, only the population growth and the recycling rates will be considered, while the GDP and inflation are assumed to be constant. From Table 8, the following graph was created.

Problems with financial allocation in waste management usually arise at the budget stage. If proper projections are done, it provides a frame of reference for potential external support. The failure to deliver adequate basic waste management service in urban centers at the right time can result in litter and illegal dumping which can cause unexpected budget strains. According to Ms C Venter (Pikitup Special projects manager), it costs R170 million a year to clean street litter and illegal dump sites, which is money that could be used on a number of other projects to bring the city up to world-class standards. Such a massive potential capital loss is avoidable if future waste volumes are reasonably accurately forecasted. Planning is paramount to the successful management of waste but should be based on anticipated future scenarios. In waste management, especially MSW, the main driver of waste is population and at least population trends are predictable. Population growth has a direct relationship on the quantities of waste generated and this is directly also linked to the GDP. The GDP gives an indication of the present and future waste per capita and therefore is quite directly linked to waste volumes.

Table 11. Calculations table to determine the exact recycling rate required.

To reduce waste to landfill		
Waste to landfill (kg)	**Difference in recycling (kg) (b)**	**Recycling increase of 2% of generation**
1,883,875,960	0	0.0
1,789,682,162	169,548,836	8.7
1,615,188,151	503,916,097	23.8
1,384,821,941	998,882,140	41.9
1,127,946,126	1,660,650,497	59.6
872,783,211	2,519,970,964	74.3
641,575,861	3,651,340,522	85.1
448,036,352	5,201,148,742	92.1
297,236,470	7,434,063,410	96.2
187,333,110	10,816,717,335	98.3
112,163,253	16,176,519,529	99.3
63,798,468	25,011,880,311	99.7

Conclusion

The projection of future waste volumes and associated expenses can be done with limited accuracy due to population dynamics. Often unforeseen natural disasters happen which may reduce the population but would not significantly negatively impact on envisaged budget. Although the model may have a limited accuracy, it is important and essential to have an estimate of future trends and environment for planning purposes in line with the tariff development strategy. The tariff strategy is to accommodate any future economic instruments and recognize the importance of tariffs in encouraging waste reduction, recycling and re-use or other environmental objectives. While the projections are based on previous and present waste trends the model only provides the background on which to base planning and possibly make decision of adoption of alternative strategies for managing waste dependent on the projected waste quantities. The model also assists to project the necessary future waste management financial resources required to avoid risk, due to incapacity caused by under allocation of resources. The key to the success of such models is working with data dependent on realistic and supported goals. Model provides long-term forecasts and scenario planning, but effective waste management should always come down to detailed, sound integrated waste management planning.

RECOMMENDATIONS

The model is the author's original work and it has not been implemented before. The City of Johannesburg Metropolitan and South Africa data was used for illustration purpose. It can be used in any country at municipal, provincial and national level for the approximation of future waste volumes and resources required. In an effort to take control of the future environment, efforts are being done by communities to forecast future waste trends. By 2004 City of Cape Town was in a bid to develop a waste generation model to integrate in the IWMP to use as integral part of the City's proposed Information System, so that it can be regulated on regular bases and used as management tool for future decision-making (City of Cape Town IWMP, 2004). It is advised that when using this model special attention should be paid on the recycling targets details. If nothing is being practically done to meet such targets the aspect of recycling would have to be left out in the model otherwise the model becomes useless or inapplicable.

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ANNEXURE

The creation of the table of values is based on the shown calculation.

Population projection

Po = P (2001)
P1 = Po (2002) = Po (1 + Pg/100)
P2 = P1 (1 + Pg/100) = Po (1 + Pg/100)* (1 + Pg/100) = (1 + Pg/100) ^2
Pi = (1 + Pg/100) ^ i

Waste quantity projection

WQo = WQ (2001) = Po * Wp

Determination of the rate of increase in recycling and recycling rate

WQo = WQ (2001) = Po * Wp
WQ1 = WQ (2002) = Po(1-q/100) * Wp
WQi = WQ (200i) = P1-I (1-q/100) * Wp

Therefore;
For the equation since Wp is constant it can be left out to remain with
For year 2001 is Po and for 2002 the equation is Po (1-q/100)^2 and for the year 2012 the equation is Po(1-q/100)^12

Therefore as per Polokwane declaration: The Waste for 2012 should be half of the waste produced in 2001 and so:

P(2001)/P(2012) = 0.5

Then Po/Po(1-q/100)^12 = 0.5

Therefore (1-q/100)^12 = 0.5
12log (1-q/100) = log 1 – log 2 = -0.303010
1-q/100 = 0.925
q = 0.025

After determining the approximate rate at which recycling can be gradually increase by use of the formula in the spread sheet the yearly recycling rate can be determined as per target by gradually adjusting the q to get to the required waste to be recycled.

Whereby:
P – Population
Pg – population growth
Wp – Waste per capita (Assumed constant over the 11 year period)
WQ - Waste quantity
Wg – Waste growth
q – Rate of recycling increase between subsequent years

ANNEXURE

Table 1. To reduce waste to landfill.

Waste to landfill (kg)	Difference in recycling (kg) (b)	Recycling (1.04%) of generation
1,883,875,960	0	0.0
1,864,283,650	94,947,348	4.8

Table 1. cont.

1,825,708,191	293,396,057	13.8
1,769,336,448	614,367,633	25.8
1,696,872,340	1,091,724,284	39.1
1,610,451,327	1,782,302,849	52.5
1,512,536,011	2,780,380,372	64.8
1,405,799,969	4,243,385,125	75.1
1,293,007,436	6,438,292,444	83.3
1,176,896,313	9,827,154,132	89.3
1,060,071,279	15,228,611,502	93.5
944,912,559	24,130,766,221	96.2

Table 2. To reduce waste to landfill.

Waste to landfill (kg)	Difference in recycling (kg) (b)	Recycling increase of 2% of generation
1,883,875,960	0	0.0
1,846,198,441	113,032,558	5.8
1,773,088,983	346,015,265	16.3
1,668,817,166	714,886,915	30.0
1,539,263,818	1,249,332,805	44.8
1,391,372,577	2,001,381,598	59.0
1,232,536,797	3,060,379,587	71.3
1,069,996,664	4,579,188,430	81.1
910,313,596	6,820,986,284	88.2
758,971,923	10,245,078,521	93.1
620,135,320	15,668,547,462	96.2
496,561,792	24,579,116,988	98.0

Table 3. To reduce waste to landfill.

Waste to landfill (kg)	Difference in recycling (kg) (b)	Recycling increase of 2% of generation
1,883,875,960	0	0.0
1,789,682,162	169,548,836	8.7
1,615,188,151	503,916,097	23.8
1,384,821,941	998,882,140	41.9
1,127,946,126	1,660,650,497	59.6
872,783,211	2,519,970,964	74.3
641,575,861	3,651,340,522	85.1
448,036,352	5,201,148,742	92.1
297,236,470	7,434,063,410	96.2
187,333,110	10,816,717,335	98.3
112,163,253	16,176,519,529	99.3
63,798,468	25,011,880,311	99.7