Chapter 3: Data Collection Regarding Solid Waste

Chapter 4: Population and Socio-Economic Characteristics of the Study Area

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The availability of information regarding the population and its characteristics is a precondition for studying the amounts of waste generated and preparing forecasts. Information regarding population size is essential in estimating the weight of waste produced per person, or per employee, which is a basic characterization of the situation in the city. The estimation of expected population size and its characteristics is necessary in preparing short-term and long-term forecasts.

Chapter 5: The Study Area

Municipal boundaries are not necessarily the most effective geographical unit choice for collecting data. Delimitation of the study area depends on the issue under consideration. When waste collection is the subject of the study, and if collection is the responsibility of the municipality (responsibility does not necessarily imply collection), then the geographical study area coincides with the municipal area.

However, if we are considering the construction of an incinerator that will serve a number of municipalities, the geographical study area should be composed of the corresponding localities.

If we are interested in preparing a forecast of waste produced in industry, including the number of employees that might be required, then the geographical study area has to be extended to include localities outside the municipal borders from which commuters travel to work in the city. In this case, the study area can reflect the labor market situation, and the study area will coincide with the metropolitan area, (including the commuting area), extending the geographical area to include localities outside the municipal borders.

Chapter 6: Population

Data regarding the population within the study area is necessary for additional analysis. Data regarding the current population is often based on population censuses or on the records of the Registrar of population. Forecasts are published from time to time as part of national or local statistical publications, and sometimes in conjunction with physical plans for the area under study. If forecasts are not available, it is possible to rely on the data relating to previous trends in the city with regard to (a) the annual growth rate (birth rate minus death rate) and (b) the annual net migration rate. The sum of these rates equals "the local growth rate", which enables calculation of the population in future alternative periods. If local growth rates are not available, we can rely on the published national values.
A formal presentation of forecast calculation:

Assuming that the population in the base year is $P_0$ and that the growth rate is $\theta$, the expected population in year $t$ would be: $P_0(1+\theta)^t$

It is preferable to prepare a range of minimum and maximum values for the forecast. We can assume alternative growth rates of $\theta = 2, 3, 4\%$. The horizon of the forecast is alternatively: $t = 5, 10, 15, 20$ years. Note: As the time span increases the reliability of the forecast decreases.

Chapter 7: Socio-Economic Characteristics

Any forecast should reflect the hypotheses regarding the socio-economic characteristics that affect the production of waste.

Income Level

Comparison between cities with different income levels, or between countries in different stages of economic development, shows that the amount of waste produced depends on income level. It is desirable to collect data on the average income level, on the income inequity and the expected growth in income level, and their added effect on the type and weight of waste produced. Such data is valuable for use in estimating the quantity and type of waste.

Age Groups

The age structure of the population is of relevance to the amount of waste produced and to its content. It is advisable to collect data on the percentage of the population in a few age groups, at minimum: 0–4, 5–18, 65+.

The emphasis placed on the 0–4 year age group stems from the fact that this group contributes diapers to the waste, which in Israel (BioTech Environmental Company, 1995) accounts for 3% of the total waste volume. The young and the old also have high hospitalization rates, and consequently, contribute to the amount of medications in the waste. Medical waste, which is often toxic, and in many countries is disposed without separation, requires special attention (regarding hospital waste, see Chapter 4).

The percentage of children in the 5 – 18 year age group provides the basis for estimating the population of students, enabling researchers to forecast the production of waste in educational institutions, including a high volume of paper.

Number of Employees

Many core cities attract employees from outside the municipality. The current number of employees provides a basis for preparing forecasts.
If data is available by industry type (e.g., food industry, textile, paper and paper products) or industry size (e.g., large scale: 500+ employees, medium scale: 101 – 500, small scale: 5 – 100 and very small scale: less than 5 employees), this can be helpful in fine-tuning the forecasts.

Assuming that we can predict the values $Q^i_t$, $W^i_t$ values,

Where:

the numbers of producers of waste of type $i$ in period $t$;
the waste produced per each producer of waste of type $i$ in period $t$.

We can produce a forecast of the waste contribution of employees by types: $\sum Q^i_t W^i_t$.

Cultural Background

Cities diverge in their characteristics, and in the attributes of different groups within the city. Different nationalities might be represented in the city, and if they diverge in lifestyle and, consequently, in the production of waste, the data should refer to the individual groups. In Haifa, the population can be divided by nationality: Jews and Arabs. Within each group, religious sects differ from non-religious groups with regard to waste production.

Chapter 8: Data Collection Regarding Quantity and Characteristics of Solid Waste

Chapter 9: Introduction

The collection of data regarding the amount of waste within the municipality is a basic step in selecting optimal solutions for the various stages of the waste treatment. This information is required by any municipality which plans to transfer the waste to a landfill, where tipping fees are charged to pay for waste transfer by weight or volume, or to pay for another stage of waste treatment. The municipality should know the amounts of waste produced within its jurisdiction in order to allocate adequate financial resources to finance its proper collection and treatment. The amounts of waste involved also affect the methods of collection and treatment chosen.

Based on Chapter 2, we assume that the amount of waste depends on the size of the population, the size of the workforce, the number of tourists and visitors from out of town, and on socio-economic characteristics.

Statistics regarding the total amount of waste are not sufficient for the preparation of forecasts, and detailed figures by types of waste producers are necessary. A reason for the need of detailed information is that there are different rates of change in waste quantity and in types, according to waste producer origin.

The amount of waste produced within the municipality (see discussion in Section 3.1.1 regarding the "study area") is the sum of the following products:

- Number of residents $\times$ the quantity of waste produced per resident.
- Number of workers in industry $\times$ the quantity of waste produced per worker.
- Number of workers in commerce $\times$ the quantity of waste produced per worker.
- Number of residents living in homes for the elderly $\times$ the quantity of waste produced per resident.
• Number of students in educational institutions × the quantity of waste produced per student.
• Number of tourists and other visitors in hotels and resorts × the quantity of waste produced per visitor.

Let us define: 

\[ N_i^t \] – number of producers of waste of type \( i \) for period \( t \);

\[ W_i^t \] – is the quantity of waste produced per each producer of waste of type \( i \) for period \( t \);

\[ N_i^t W_i^t \] – the total amount of waste in period \( t \) produced by a producer of type \( i \);

\[ \sum_i N_i^t W_i^t \] – by all types of producers.

In studying the total amounts of waste, data regarding the number of producers (\( N_i^t \)) is based on publications, such as: population censuses, data on the workforce, educational institutions, tourists, visitors and on corresponding forecasts.

Data regarding the amounts of waste per producer \( i \), is based on current measurements regarding the present situation, and on forecasts for coming years.

Chapter 10: A Methodology for Collecting Data on Waste

The emphasis in this section is on the quantities and the characteristics of the waste produced within the municipality, specifically – on residential waste. Occasionally, we shall address the quantities of waste created by other producers, as well.

Estimating the total amount and content of the waste produced over a certain period is the first step towards producing any forecast. In estimating the weight and the content total enumeration, a random sample or stratified sample can be used.

In Section 3.2.2.1, we discuss different issues regarding the survey period, the information required, etc. In Section 3.2.2.2, we describe the method of total enumeration, and in Section 3.2.2.3, we address the question of random samples vs. stratified samples. In Section 3.2.3, we report our experience in Haifa in estimating the total amount of waste.

Chapter 11: Survey Period

In estimating the amount of waste produced within the municipality, a first step is to estimate the total amount before proceeding to a detailed study.

In planning the experiment, we have to decide whether we are interested in the average weight or the weight of the waste material in exceptional periods. This question is equivalent to asking in which period to conduct the survey? Is there a certain preferred survey period, and alternately, which periods are to be excluded?

Decisions regarding the survey period should rely on previous experience in the city or country, and if there is no previous experience, on the experience gained in other countries. An
interest in surveying extreme values will lead us to perform the survey during a period of holidays, festivals and other exceptional events. It should be emphasized that the variation between months and between days of the week is significant and cannot be disregarded.

If the question arises whether we need information on peak, average or low quantities, we should be aware that plans are created by taking peaks and lows into account. In designing a collection system, the number of trucks used should vary according to previous experience with respect to variations. Planned vacations of waste collection employees should not take place during peak periods, or alternatively, the number of workers should be increased during periods of festivals, or during peak tourist periods.

Other questions we should ask are:

- Do we prefer a certain day of the week to others?
- Do we have to weigh in at certain hours, or at all hours of the day?
- Can we identify a means of transportation (e.g. compactors) to enable a minimal number of weighings, and which information do we lose in by making this choice?

**Chapter 12: Total Enumeration vs. Sampling**

The choice between using a sample or total enumeration (during a certain day, or a week) depends on the cost of conducting the survey (cost of weighing a single truck, the availability of a weighing station, the cost of surveyors, etc.). When using samples, we use either a random sample, or we can prefer a stratified sample.

MODECOM recommends performing a random sample. In a random sample, each truck or compactor (if this is the unit sampled) has the same probability of entering the sample. MODECOM recommends taking a sample of five or ten observations per day. Total enumeration requires the weighing of all the trucks in the municipality. This method is often too expensive to be executed, particularly if the city is large and has a large number of units to examine. In large cities the major advantage of using a sample is its lower cost.

**Chapter 13: Designing a Stratified Sample to Study Residential Waste**

Studies performed in different cities and countries show that the variation in the quantities of waste produced, and in its content, reflect socio-economic level. While a random sample can reflect the amount of waste and its characteristics, by designing a stratified sample we can increase the accuracy of the estimates (if the number of observations is the same as in a random sample). Alternately, we can reduce the size of the sample (while achieving the same accuracy). Regarding the difference between stratified random sampling and random sampling, see Appendix 3. In a random sample, a percentage of compactors, or of containers, is weighed and/or examined; where in a stratified sample, the samples are taken from each strata.

The stratified sample is intended to reflect the variation in a cross-section sample. The city has to be stratified to reflect the hypotheses. An easy unit for stratification is the neighborhood, since neighborhoods are homogeneous in many socio-economic characteristics. The neighborhood is also a unit on which statistical data, which is the basis for stratification, is often available. In Israel, large neighborhoods are divided into statistical sub-units, for which data is collected. However, statistical data is not collected for these sub-units on a regular basis. In Israel, statistical data for these units is collected only for the Housing and Population Census, which is conducted once every 10-12 years. If updated data from a census is available, we can stratify the city according to our hypotheses. Otherwise, if
updated detailed data is not available, we can stratify the neighborhoods according to available data on the size of apartments, housing density, student educational achievement levels, etc.

We expect the amount of waste to depend on socio-economic level, as indicated by income level, educational achievements, housing density, percentage of unemployed, age structure or other indicators. National origin and other cultural characteristics of the neighborhood's residents might also affect waste, since consumption habits can differ, as do other customs. Another distinction is whether the neighborhoods are purely residential, or mixed with commerce and/or industry.

The decisions to be made are:

- Shall we use a random sample or a stratified sample?
- What are the strata to be examined, which hypotheses are reflected in their choice?
- Are we interested in residential, institutional, commercial or industrial waste?
- What is the total number of observations, and how many observations shall we take in each stratum?

The number of observations is influenced by the cost of obtaining each observation, in addition to statistical reasoning considerations.

Chapter 14: Studying Quantities

Studying quantities of waste requires the weighing of the trucks/compactors selected. MODECOM describes the technical requirements necessary for weighing.

Chapter 15: Studying Characteristics

In studying the characteristics of waste we first have to define the components which are of interest. MODECOM (p. 26) suggests the following categories:

1. Fermentable waste. 7. Plastics.
5. Textiles. 11. Unclassified non-combustibles.

The classification should be adjusted according to prior knowledge and the objective of the study. Categories 2 and 3 can be combined into a single category, if paper and cardboard are intended for recycling. Alternatively, Category 1 can be split into garden waste and other organic materials, if we need a forecast of the number of vehicles needed for the collection of garden waste.

The sample should be sorted according to the components defined. Each component can be examined in terms of weight, volume, humidity, and toxicity. The results are multiplied according to the appropriate pre-defined factor. For detailed technical directions consult MODECOM.
Chapter 16: Case Study: Studying Residential Waste in Haifa

Waste is not regularly weighed in Haifa. A decision was made to study the average daily weight of waste and not the extreme quantities. As a first step, all compactors and crane vehicles in the city were weighed. The compactors are a link between the transfer station and the landfill. They are few in number, and consequently it required a limited number of weighings.

Total enumeration was preferred to a sample. This decision reflects three facts: the small number of vehicles, the fact that the city owns the weighing station and that the surveyors are municipal employees and were not compensated for their work.

Period of Survey

Choice of month: Having studied the available data from 258 municipalities in Israel, we inferred that there is a monthly variation in the amounts of waste produced. The variation reflects holidays, periods when schools are open or closed, the number of tourist arrivals and departures, etc.

We selected a single month, which is associated with average waste amounts: May. Only weighing all year round can represent monthly variations, whether May actually represents the average and which are the extreme months with the minimum and maximum values.

Choice of day: We debated between selecting a single day of the week, which in other cities constitutes the average, or whether to give preference to a day on which quantities are either maximal, or minimal. Since our purpose is to obtain more detailed information on waste, we preferred not to choose extreme days, but rather an 'average' day. We decided to conduct the survey over a full week, in order to obtain data regarding the variations within a week, and between the different hours of the day. We could have limited the number of hours of the day in which the survey takes place, however we decided to perform weighings throughout the entire day, according to the truck operating times.

In the second stage, we were interested in obtaining more detailed information to enable us to infer with regard to variations between neighborhoods, in terms of the quantity of waste produced, as a function of socio-economic characteristics.

The waste in Haifa is collected in bins of various sizes. Some of the residential waste is collected in small bins and transferred in compactors, while other waste is collected in containers, which are individually transferred to transfer stations, which are located in two sections of the city. Analyzing the location of the containers throughout the city, we realized that they can provide highly detailed information and enable the study of the relationship between quantity of waste and socio-economic characteristics.

All 700 containers in the system were weighed throughout a week in May. Each container was weighed 2-7 times, according to the number of collections made during the week. The weight of each container was recorded. The containers are identified by their exact location, and in addition to socio-economic level, we know whether its origin is from a purely residential, mixed function, or purely commercial area (e.g., a market or a shopping center), an educational institution, a hospital or an home for the elderly.
Chapter 18: Conclusions and Recommendations Stemming from the Survey

During the experiment each empty truck was weighed daily, at the end of the workday. The net weight of each container was taken from the technical data provided by its manufacturer. Each truck, with container, was weighed upon arrival at the transfer station, and the net weight of its waste was calculated by subtracting the known weight of the truck and container. In analyzing the results, we concluded that it would be better to weigh each truck as it entered and exited the site. The inaccuracies result from the following causes: The weight of the waste is small relative to the gross vehicle weight, and any inaccuracy is reflected in the net recording of waste. The weighing should either consistently include, or exclude the driver. For the sake of saving time it would be better to allow the driver to stay in the truck. The weight of the fuel relatively to the net weight is high. The weight of the containers diverges from the technical data provided by the producers (a container's weight can change, for example, if it has undergone repair).

Chapter 19: Designing a Stratified Sample

Data on socio-economic characteristics enabled us to define strata within the municipality. The hypothesis is that the higher the socio-economic level, the waste produced differs in both amount and its characteristics. This hypothesis lead to the choice of three socio-economic strata - low, medium and high. Additional strata reflect cultural variations within the city. We hypothesize that a neighborhood in which the majority of its residents belong to a religious sect with a high fertility rate produces a different amount of waste than a neighborhood with a similar socio-economic level.

Another stratum reflects the hypothesis that ceteris paribus a neighborhood with residents of Arabic origin produces a different amount and type of waste than a neighborhood with residents of Jewish origin.

The strata chosen were:

- Jewish – high (Type 1), medium (Type 2) and low (Type 3) socio-economic level.
- Jewish – religious sect and low socio-economic level (Type 4).
- Arab origin and low socio-economic level (Type 5).

Altogether, the five socio-economic strata above were defined.

When studying the content of waste, we use the stratified sample that was designed. Each container, or bin, that was selected is weighed upon arrival. The contents of containers originating from the same socio-economic strata are studied according to the directions in MODECOM.

Forecasting Magnitude and Characteristics

As shown in Section 3.1.1, the amount of waste depends on the size of the population and the amount of waste produced per person. The same approach can be adopted when discussing the amounts of certain components within the waste. In preparing forecasts we have to prepare
3.2 Data Collection Regarding Quantity and Characteristics of Solid Waste

Forecasting the size of the population and, specifically, the waste of component \( j \), requires econometric analysis of the waste. This analysis provides us with an equation that presents the relationship of waste as a function of socio-economic characteristics.

Where:

\[
W_{ijt} \quad \text{is the waste per producer of type } i, \text{ waste of type } j \text{ over period } t.
\]

If \( X_{1i} \), \( X_{2i} \), \( X_{3i} \) denote socio-economic characteristics of producer \( i \), then the relationship \( W = F(X_1, X_2, X_3) \) will display the effect of the characteristics. Substituting the mean value of the characteristics in different periods enables us to calculate the waste per producer.

Once we have forecasts of the population and waste per producer in different periods in the future, the product will provide us with the required forecast.

Bibliography