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Characterization of Household and Commercial BMW Generation According to Socio-economic and Other Factors for the Dublin Region

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Abstract: Both planning and design of integrated municipal solid waste management systems require accurate prediction of solid waste generation. This research predicted the quantity and distribution of Biodegradable Municipal Waste (BMW) generation for the Dublin (Ireland) region. Socio-economic variables, housing types, and the sizes and main activities of commercial establishments were hypothesized as the key determinants contributing to the spatial variability of BMW generation. A Geographical Information System (GIS) 'model' of BMW generation was created using ArcMap, a component of ArcGIS 9. Statistical data including socio-economic status and household size were mapped on an electoral district basis. Historical research was used to assign BMW generation rates to residential and commercial establishments. These predictions were combined to give overall BMW estimates for the region. The GIS facilitates the visual and spatial distribution of BMW to be assessed within the region. BMW generation was predicted within a diverse 'landscape' of residential areas, as well as from a variety of commercial establishments (restaurants, hotels, hospitals *etc*). By changing the input data, this estimation tool can be adapted for use in other Irish cities.

Keywords: BMW; Dublin; Geographical Information Systems (GIS); socio-economic factors; household waste; commercial waste

Introduction

Waste management is widely recognized as one of the most problematic areas of Irish environmental management. With the rate of waste generation continuing to increase and existing waste disposal sites reaching the end of their useful lifetime, waste management has become a matter of urgency (Forfás, 2001). Some 72% of household and commercial waste is considered biodegradable municipal waste (BMW). It is estimated that

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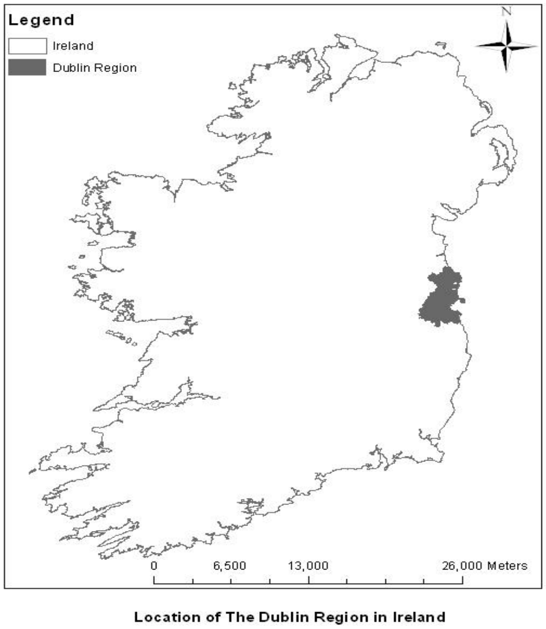
approximately 2,007,900 tonnes of BMW was generated in Ireland in 2005, of which 65% was landfilled and the remaining recycled (EPA, 2006).

Economic growth during the last decade has stimulated greater consumption throughout Irish society, so waste management issues have become increasingly important (Fahy *et al*., 2004). Ireland's economy is now the fastest growing in Europe. As gross domestic production (GDP) has increased, so has the volume of waste produced, therefore economic prosperity affects waste generation by stimulating increased consumer activity and business expansion (Mazars, 2003). It is important to focus on waste prevention – to decouple waste creation from economic growth – and reverse current waste trends.

Both planning and design of integrated municipal solid waste management systems require accurate prediction of solid waste generation. However, to achieve world-class waste management objectives through a process of continuous improvement, it will not be enough simply to know the gross quantity of wastes being generated; both the quantity and spatial distribution of waste must be defined. With this specific knowledge it will, for example, be possible to target waste prevention strategies to locations in which they are most needed.

The aim of this research was to develop a reliable and realistic model for determining the BMW generation from both the residential and commercial sectors within the Dublin Region. This was achieved by identifying, defining geographically, and characterizing the residential sector, as well as various commercial waste generators, and then translating this information into maps of waste generation for the Dublin Region. This paper describes the resulting GIS-based estimating system that can be used to quantify the generation of BMW in the Dublin (Ireland) region (Figures 1 and 2). The system application requires housing and demographic statistics as well as the locations and types of commercial activity. The system facilitates the visual and spatial distribution of BMW to be assessed within the region. By changing the input data, this estimation tool can be adapted for use in other Irish regions.



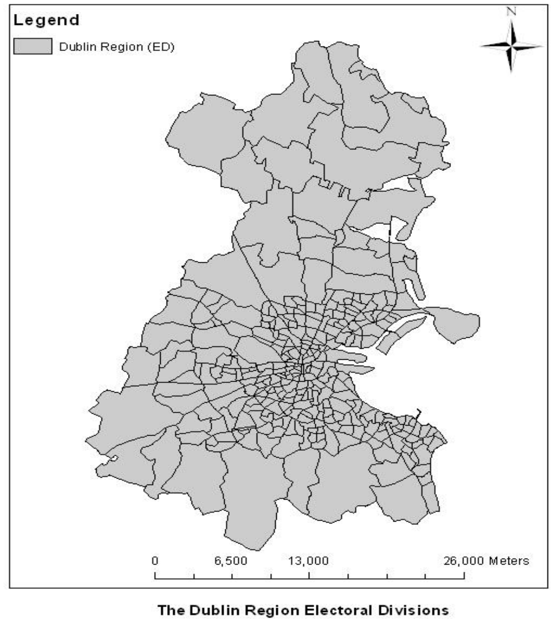


Figure 1. Location of Dublin **Figure 2. Dublin Electoral Districts**

Goal of the study
The main goal of the study was to identify, locate, and quantitatively evaluate the sources of BMW generation in the Dublin region and also to map this waste generation.

Scope of the study
Seven commercial sectors were deemed to occur frequently in the Dublin Region, as well as contribute significant quantities of BMW. This study also took into account the entire residential sector in the region.

a) Study Area

The Dublin Region (Figures 1 and 2), consisting of 92,227 ha, was the study area. The Dublin Region is comprised of four Local Authority areas, namely Dublin City, Fingal, South Dublin and Dún Laoghaire-Rathdown.

b) Study scale

The scale of study was conducted at the Electoral District level (the smallest administrative area for which population statistics are published). There are 322 Electoral Districts located throughout the Dublin region, all of varying sizes (e.g., “Ushers” of 14 ha to “Lusk” with 4238 ha) and ranging from inner city districts with high population densities to rural areas with dispersed populations.

Materials and Methods

Overview
The ArcMap application, a component of ArcGIS 9 (ESRI, 2005) was used in this study to map the locations of commercial and residential establishments. These input data were readily available from the Irish Central Statistics Office (CSO), Ireland’s agency charged

with recording the country's vital statistics, and from the An Post / Ordnance Survey Ireland GeoDirectory (2006), a listing of all commercial establishments together with their geographic co-ordinates and other data. Data from the Dublin Transport Office (DTO, 2007) was used to map education numbers.

Data collection and generation

The CSO statistics described the demographic profile (e.g., house types, number of occupants, household incomes, *etc*.) of the entire residential sector for the Dublin Region. However, in order to determine which commercial sectors might contribute most to the commercial waste stream, a comprehensive literature survey was conducted. Applicability of data to the Dublin region, and ability to access data related to the sector were taken into account as part of the survey. As a result, seven commercial sectors were deemed to be the most significant producers of commercial BMW and were included in the study:

- Supermarkets;
- Hotels;
- Restaurants;
- Takeaways/fast-food establishments;
- Education (primary, secondary schools, and 3rd level);
- Hospitals;
- Public houses (e.g., bars, lounges);

The following procedure was used to analyze the commercial sector:

1. Identify each member (from the above list) of the commercial sector;
2. Plot geographic co-ordinates and assign facility to the appropriate Electoral District;
3. Apply waste generation rate (obtained from published research) to each commercial establishment;
4. Calculate predicted commercial BMW generation rate.

A similar procedure was used to analyze the residential sector:

1. Map the residential sector and characterize each Electoral District by the demographic profile of the residential sector;
2. Apply waste generation rates (obtained from published research) to residential sector.

Finally, predicted waste generation rates for the commercial sector were added to those of the residential sector to estimate total BMW generation rates for each Electoral District for the region.

Preparing and analysing commercial sector information

Describing the commercial waste sector entailed identifying the sectors likely to generate significant amounts of BMW and plotting these locations on the Electoral District basis. These sectors were then added together to create an overall commercial BMW generation rate.

A total of 2,261 commercial points (unique commercial establishments) belonging to the seven different commercial sectors were identified. Site locations for the commercial point sources were mapped using data from a number of sources including Kompass Ireland, an electronic database of businesses (Kompass Ireland, 2006); the Department of Education and Science (Department of Education and Science, 2006), the Dublin Transport Office (DTO, 2007) and the CSO (i.e. SAPS, Small Area Population Statistics, 2002). In addition, locations of schools were manually digitising using ArcGIS 9 from published paper maps (OSI, 2002). The education sector was investigated on an education place number basis for each Electoral District.

ArcGIS 9 (ESRI, 2005) and ArcView *v*3.3 (ESRI, 2005) were used to map points or relate address points to Electoral Districts for plotting. The An Post / Ordnance Survey Ireland GeoDirectory 2006 (An Post & Ordinance Survey Ireland, 2006) was also used to verify the accuracy of points and to map some data points.

A variety of data were collected to characterize each member of the commercial sectors included in this study:

- The size and nature of each establishment (all sectors)
- The number of employees (all sectors)
- The number of education places (schools, colleges/universities)
- The number of bedrooms (hotels)
- The number of beds (hospitals)
- The composition of waste generation (all sectors)

Hotel bedroom numbers and hospital bed numbers were acquired by contacting the specific establishment and / or by accessing internet sites for the up to date figures.

Waste generation rates for the various categories comprising the commercial sector were taken from published research, specifically the following:

- Massachusetts Department of Environmental Protection (2002)
- CIWMB (2004)
- Hogan *et al*. (2004) [EPA]
- EPA (2005)
- CIWMB (2006).

Waste generation rates only were analysed in the study. Disposal rates or diversion rates were not calculated. Waste generation rates were used to create a 'BMW Generation Equation' for each commercial sector.

Lastly, each unique commercial point was assigned the relevant attribute data (e.g., number of employees, numbers of hotel rooms *etc*.) and waste generation rate equation. Together these data were used to quantify and characterize the waste generated. These data were then integrated with the Electoral Division Identification Number (EDID) to aid precise mapping and apply the waste generations at the Electoral District level.

An over all 87% of geocodes were available from the Directory for mapping locations of the commercial sectors with a very high percentage available for the Hospitals at 93% and the Hotels at 88.7%. This data base is constantly being updated.

Figure 3 depicts the distribution of establishments comprising the commercial sectors studied in this research.

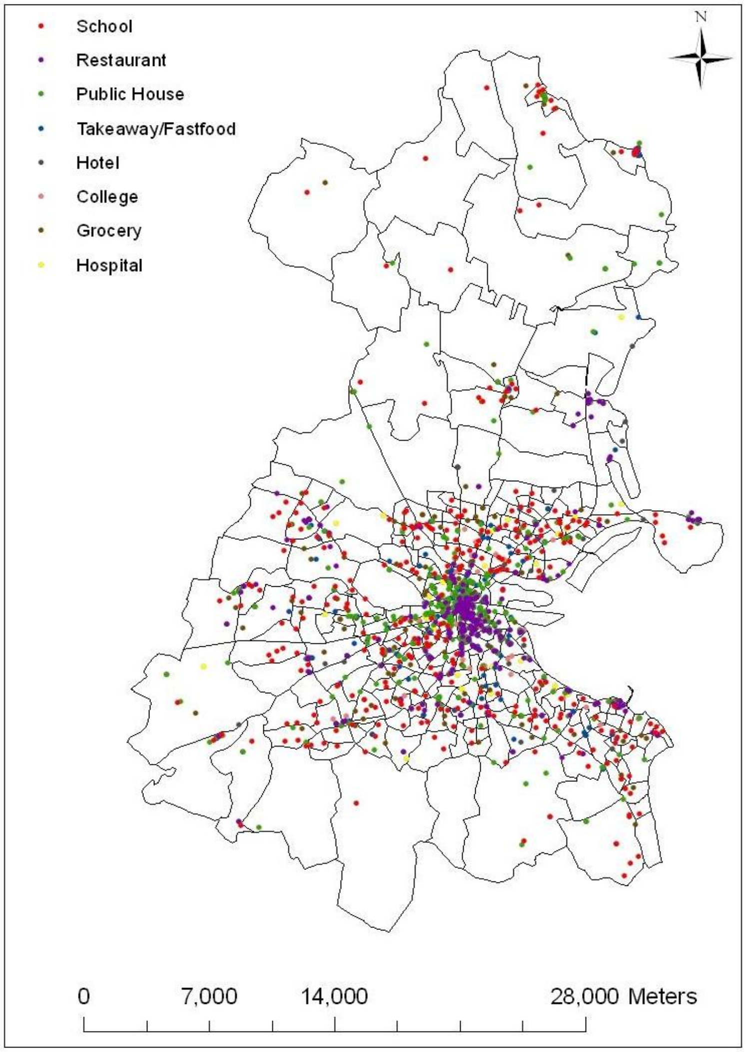


Figure 3. Commercial Point Source locations

Preparing and analysing residential information

For the residential sector the following data were gathered:

- Household size (persons per household basis)
- Social class (according to the CSO)
- Waste generation rates (determined from published literature)

Small Area Population Statistics (SAPS) (CSO, 2002) were used as the source for the first two data. Waste generation rates were determined from published research pertaining specifically to Dublin (Dennison, 1996, DeBúrca, 1995). Two estimation techniques were utilised for assigning waste generation rates to this sector: household basis and social class basis. As with the commercial sector points, waste generation rates and demographic data were assigned as attributes to the relevant geographic locations and combined to give BMW generation rates at the electoral district level.

Figures 4 and 5 are examples of how residential areas were mapped according to household size (Figure 4) and social class (Figure 5). Household sizes were registered for up to 7 persons per household; similarly there were 7 social classes.

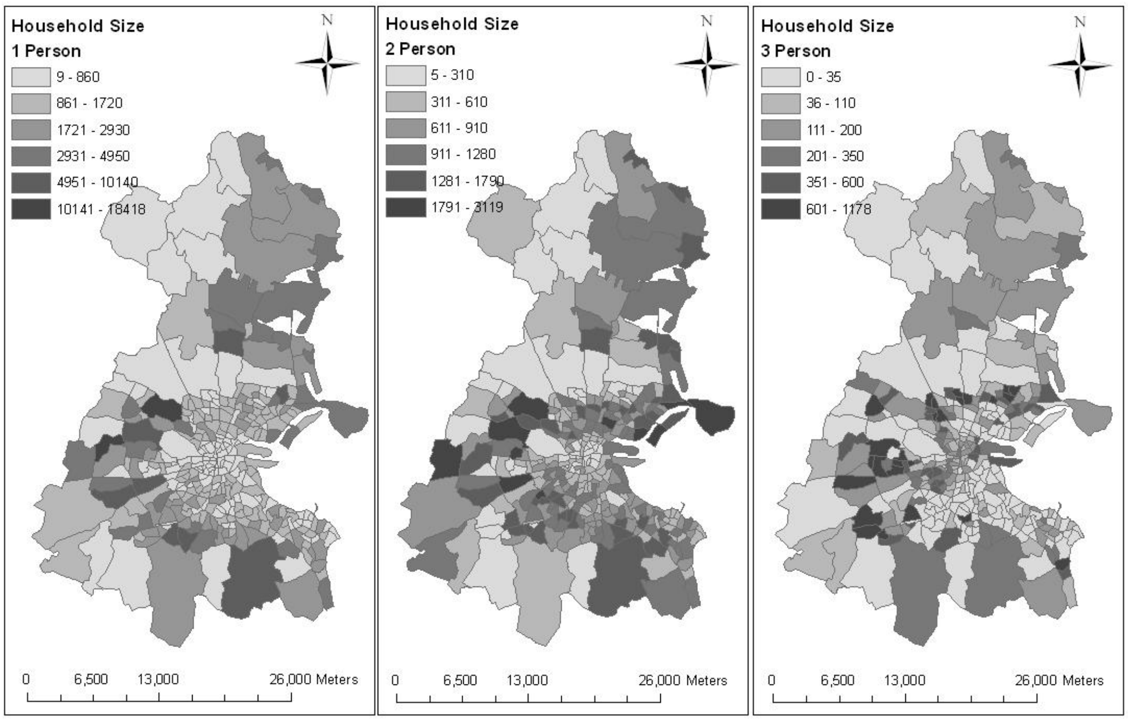


Figure 4. Example Household Size Distributions for the Dublin Region (1, 2 and 3 Persons per Household).

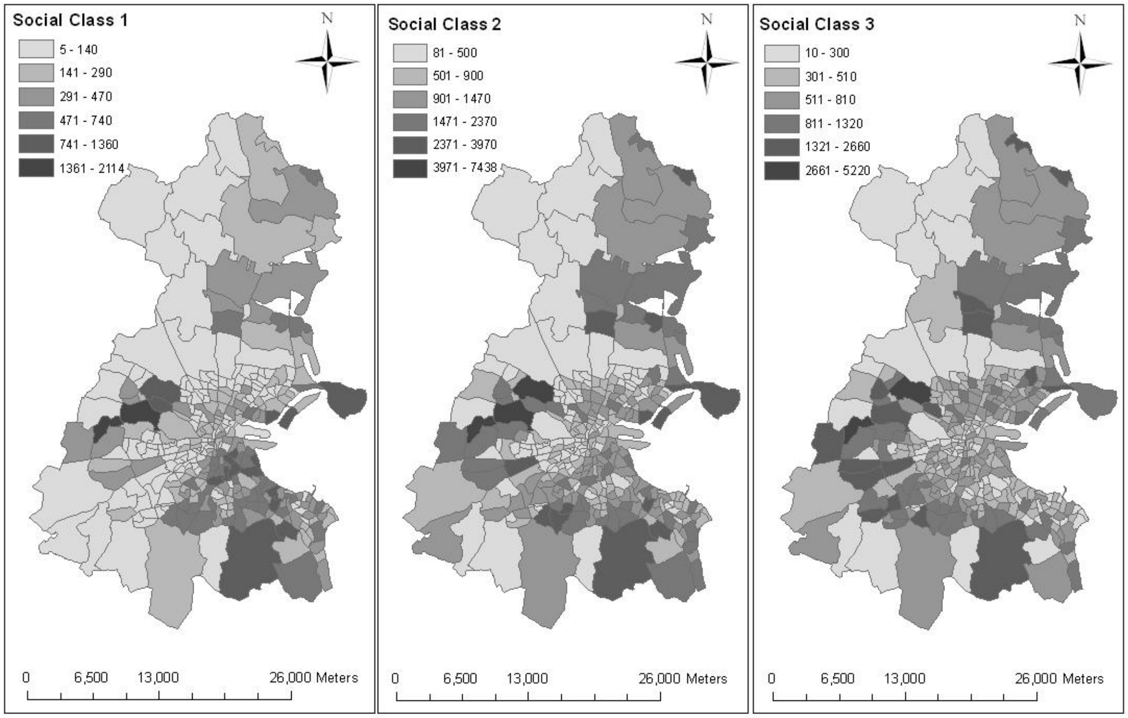


Figure 5. Example Social Class Distribution for the Dublin Region (Social Classes 1, 2 and 3).

Results

The commercial sectors that were addressed in this study were the sectors believed to be most likely to generate significant quantities of BMW in the region. Approximately 3,523 t of BMW are predicted to be generated per week by the commercial sectors included in this study (Table 1). Of the sectors studied, there are a large number of schools (primary and post primary) located throughout the Dublin Region (658). Public houses are also abundant and widely dispersed in the Region (496). The grocery sector is predicted to generate a large amount of BMW (1550 t wk^{-1}), which was expected, as there was a large number of these point sources in the region and these would generally generate a large amount of BMW, both from the delicatessen section (most small supermarkets in Ireland have a "deli" section) and also from the general sales department. The Hotel, Public House, Restaurant and Takeaway sectors together make up 35% of the overall predicted BMW generation from the seven commercial sectors examined for the Region.

There was also a large number of educational places (student seats) in the Dublin region (268576), which was also expected as Dublin, the capital city in Ireland, would also be the 'education capital' in Ireland, holding the majority of 3rd level institutions. The main education 'hotspot' was identified to be located in the Electoral District Clonaskeagh-Belfield (18020) where the 3rd level institution University College Dublin is located. The range in predicted generation rates from each electoral district (0 t wk^{-1} to 1015 t wk^{-1}) originated from Ballymun A (94 ha) [amongst others including Cabra West A (42.8ha) and Rathfarnham-Butterfield (76.8 ha)] and Dun Laoghaire-East Central (45.6 ha), respectively (Figure 6).

Table 1. Predicted Commercial BMW Generation by Sector.

Sector	BMW Generation ($t\ wk^{-1}$)	% of Total BMW Generation
Grocery	**1550.6**	**44.01**
Restaurants	**262.3**	**7.44**
Takeaways	**55.3**	**1.6**
Hotels	**535.5**	**15.2**
Pubs	**378.3**	**10.7**
Hospitals	**219.4**	**6.2**
Education	**522.1**	**14.82**
Total	**3523.5**	**99.97***

*figures do not add to 100% due to rounding

The largest predicted quantity of commercial BMW was found to occur in Electoral District Dún Laoghaire East-Central (in which several hospitals, hotels and restaurants are located) and the Electoral District Royal Exchange A (in which a large number of Public houses are located).

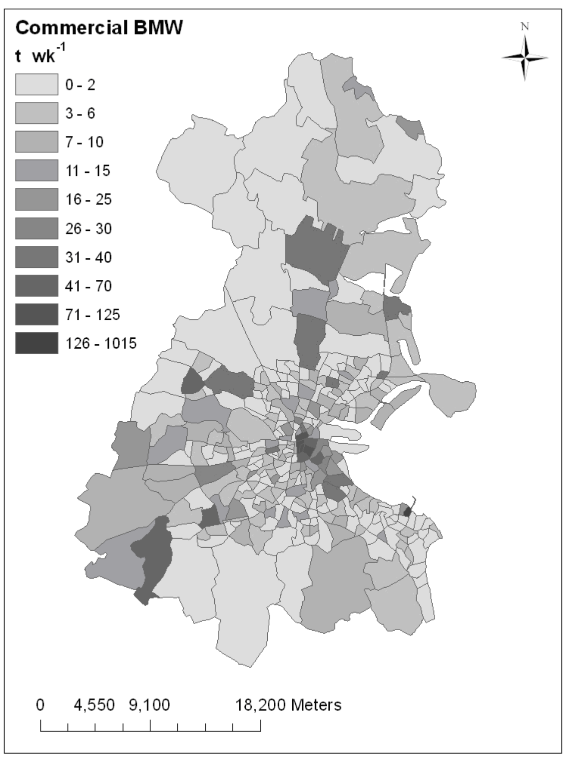


Figure 6. Predicted Commercial BMW Generation for Hotels, Hospitals, Restaurants, Takeaway, Public Houses, Education and Grocery Sectors.

The residential sector was predicted to generate significantly more BMW per week than the commercial sector (Table 2); exactly how much more depends on the methodology utilized to estimate household BMW (Household size basis = 8159 t wk^{-1}, Social class basis = 13082 t wk^{-1}). The distribution of household BMW generation predictions is shown in Figure 7. The largest amount of Residential BMW was predicted to be generated in the Electoral Districts Blanchardstown-Blakestown (284 t wk^{-1}, social class basis) and Lucan-Esker (243 t wk^{-1}, social class basis). In terms of waste generated per hectare Electoral District Cabra West C was estimated to generate potentially 1164 kg wk^{-1} ha^{-1} (household size basis), while Clondalkin-Cappaghmore was seen as a potential waste hot spot, generating 1968 kg wk^{-1} ha^{-1} (social class basis).

Table 2. Residential BMW Generation as a Function of Estimation

Estimation Technique	BMW t wk^{-1}	% Difference
Household Size	8158.58	37.6
Social Class	13081.52	

The residential sector was predicted to generate between (Household size basis) 2.31 t wk^{-1} (2 kg wk^{-1} ha^{-1}) in Lucan North (population = 338) to 32.96 t wk^{-1} (1425 kg wk^{-1} ha^{-1}) in Merchants Key B (population = 3449). On a Social class basis the results predicted were between 3.95 t wk^{-1} (4.2 kg wk^{-1} ha^{-1}) for Lucan North and 283.24 t wk^{-1} (399.71 kg wk^{-1} ha^{-1}) in Blanchardstown-Blakestown (population = 24404).

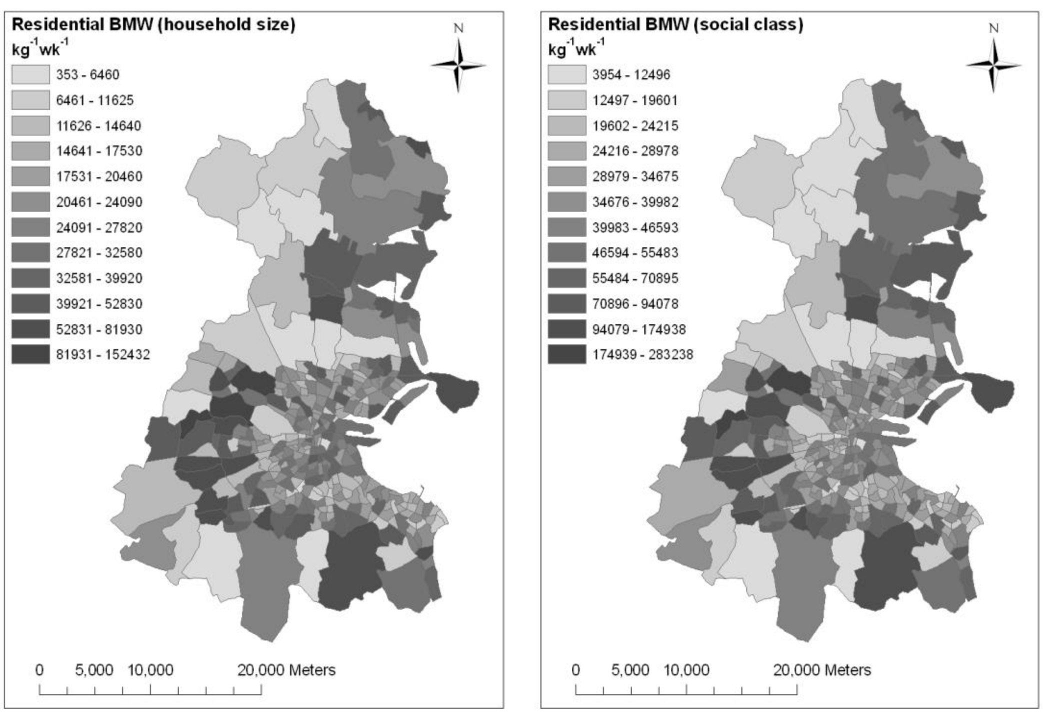


Figure 7. Distribution of Predicted Residential BMW Generation According to Household Size (left) and Social Class Statistics (right)

Combined, the commercial and residential sectors in the Dublin Region are predicted to generate 11682 t BMW wk^{-1}, when estimates are based on household size or 16605 t wk^{-1} when estimates are based on social class (Figure 8). The range in predicted generation rates (4.2 t wk^{-1} to 1032 t wk^{-1}) was expressed in Balscadden (1572 ha, population 577, employee numbers 72) and Dun Laoghaire East Central (45.6 ha, population 2144, 4248 employee numbers), respectively (Household basis), or (3.9 t wk^{-1} to 1040 t wk^{-1}) in Lucan North (940 ha, population 338, employee numbers 129) and Dún Laoghaire East Central, respectively (Social Class Basis).

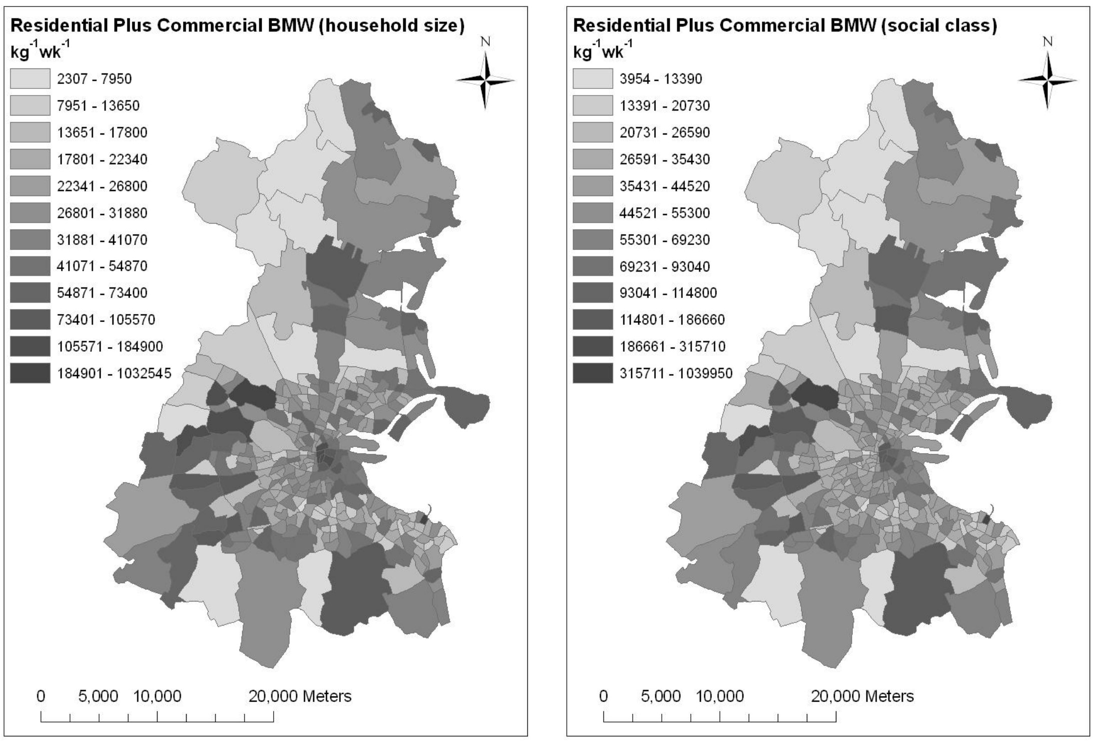


Figure 8. Distribution of Predicted Residential Plus Commercial BMW Generation According to Household Size (left) and Social Class Statistics (right).

Discussion and Conclusions

BMW generation was predicted for the Dublin region within a diverse 'landscape' of residential and commercial areas. Household type and socio-economic status, as well as the types and sizes of commercial establishments, were hypothesized as the key determinants contributing to the spatial variability of BMW generation. A GIS 'model' of BMW generation was created using ArcGIS 9 (ESRI, 2004) and used to identify the geographic patterns of commercial and residential BMW generation. These spatial patterns of predicted BMW distribution, based on generation rates from previous research, appeared to confirm the hypothesis about the importance of demographic factors in the generation of BMW.

The commercial sector in Dublin is predicted to have the potential to generate >3523 t BMW wk^{-1}; adding to this the predicted residential sector BMW (household size basis) amounts to >11682 t BMW wk^{-1} for the Region (or, on a Social Class basis, >16605 t BMW wk^{-1}). These results not only highlight the relative importance of the two sectors in generating BMW, but also suggest a large difference in estimating the potential residential BMW according to Household size and Social class statistics. Only by comparing these predictions to actual waste collection data (a process that is under way) can this discrepancy be explained. Regrettably, few data exist in the Dublin region on the actual quantities of BMW collected from households, as except for dry recyclables, the majority of municipal waste in Dublin is collected as mixed waste.

The Grocery Sector was predicted to contribute over 44% of the potential commercial waste for the region. Based on these results, key opportunities for waste diversion appear to be possible with the introduction of separate waste collections for organic wastes (*i.e.*, "brown bin" service), composting, etc. For example, the education sector is estimated to contribute almost 15% of the total commercial BMW to the region; thus the Green Schools Programme (An Taicse, 2003), should have a large impact on the Dublin Region in terms of BMW waste education and diversion.

Results from the study reported here imply that there are large variations in the generation of BMW at the Electoral District level within the Local Authority areas. Particularly obvious from large variance in BMW generation rates among district electoral divisions is how population and socio-economic factors combine to affect waste quantity and distribution of residential waste and how employee numbers affect commercial waste generation in the region. Although the predictions need to be validated by comparing them to measured data, the technique is, nevertheless, a useful managerial tool to integrate the effect of demographic and economic changes on waste management. The variations in BMW generation rates within the region highlight the importance of tailoring waste collection strategies, and, indeed, waste management education and dissemination activities, to small management areas. There is a need to improve data and information on generation and management of BMW, including projections on future waste arisings.

Precise estimation of waste generation can lead to a more rational and efficient management of waste for the region, as well as within individual local authorities. Some local authorities in the Dublin region are experiencing phenomenal population growth and the associated development. This GIS-based analysis was carried out using up-to-date small-scale (ED) statistics for optimal precision. This can aid a more functional and economical design of waste management systems to address the massive changes in waste generation patterns that accompany demographic changes. This system can also be adapted to other Regions in Ireland by altering the input data for the relevant areas.

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