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# Effects of percent operating expenditure on Canadian non-hazardous waste diversion

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ABSTRACT

In 2014, Canadians produced 961 kg per capita of non-hazardous waste, and spent about CAD$85 on waste management operating expenditure. Using aggregate data from Statistics Canada, multiple linear regression models were developed to examine diversion rates with respect to percentage of expenditure on various parameters related to waste management in Nova Scotia, Québec, Ontario, and nationally (in Canada). Budget allocation varies significantly in Nova Scotia with respect to time. On average, only 31% of the Nova Scotia's budget was spent on collection and transportation, compared to the national average of 46%. Tipping fees were only significant in the national regression model, likely because some prairie provinces are using tipping fees to increase waste diversion. The Québec model was the least statistically significant. Negative regression coefficients were identified for the operation of recycling facilities in the Nova Scotia and Ontario models, however, they were less statistically significant, suggesting a more complex relationship. A lagged relationship between increases in budget allocation for operation of organics and recycling facilities and diversion rates was found in Québec, with a lag period of about 5–8 years. Overall, the Nova Scotia model had a much higher modelling adequacy, interesting considering its highest diversion rate in Canada.

## 1. Introduction

Canadians have one of the highest non-hazardous waste generation rates in the world (Bruce, Asha, & Ng, 2016; Richter, Bruce, Ng, Chowdhury, & Vu, 2017; Wang, Ng, & Asha, 2016), generating a total of 961 kg of waste per capita in 2014 (Statistics Canada, 2017a). Because of a high availability of undeveloped land, landfilling is a logical choice for many Canadian communities (Bruce et al., 2016; Wagner & Arnold, 2008). Canadians local governments spent an average of CAD $85/capita on non-hazardous waste management operating expenditure in 2014 (Statistics Canada, 2016a, 2017c). Not surprisingly, Canadian diversion rates are relatively low, with the average Canadian only diverting about 26.5% of their waste in 2014 (Statistics Canada, 2017b).

Ontario (ON) and Québec (QC) are Canada's two largest provinces considering both area and population. Combined they have an area of 2.74 million $km^2$, about 27% of Canada's entire land area, and a population of about 21.82 million, or 61.4% of Canada's total population (Statistics Canada, 2016a). ON and QC were responsible for approximately 59% of non-hazardous waste generated in Canada in 2014, and 63% of the waste diverted in the same year (Statistics Canada 2017a,b), and both provinces spent an average of CAD $82/capita on waste management operating expenditure (Statistics Canada, 2016, 2017c). Lakhan (2016) studied the distribution of funding to Ontario municipalities and recycling rates. Using data from Waste Diversion Ontario (WDO) and modelling via regression analysis, Lakhan (2016) found that changes in recycling rates and program costs are dictated almost entirely by factors unrelated to municipal incentivization. In QC, composting expansion is limited by the low cost of landfilling and high infrastructure and maintenance costs associated with certain types of organic diversion technologies, as well as issues with public acceptance, due to odour nuisance issues (Hénault-Ethier, Martin, & Housset, 2017). Adhikari, Trémier, Martinez, and Barrington (2010) investigated the impact that community compost centres and home composting would have on future scenarios in Europe and Canada. They found that by 2025, these on-site practices could reduce costs by anywhere between 34 and 50%. Table 1 summarizes other key expenditure features and their effects on diversion rates in Canada and around the world.

Despite the poor performance of the average Canadian in terms of waste management and diversion practices, residents of Nova Scotia (NS), a maritime province located on Canada's (CA) east coast, only produced 682 kg/capita of waste in 2014, and diverted 43.4%. On average, in NS, about $109/capita was spent in 2014 on waste management operating expenditure. Many studies have investigated the success of the NS waste management model with respect to its high

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**Nomenclature**

| | |
|---|---|
| C&D | Construction and demolition waste |
| C&T | Collection and transportation |
| CA | Canada |
| CANSIM | Canadian socio-Economic information management system |
| Disp. | Expenditure on operation of disposal facilities |
| MLR | Multiple linear regression |
| NS | Canadian province of Nova Scotia |
| ON | Canadian province of Ontario |
| Org. | Expenditure on operation of organics processing facilities |
| Oth. | Expenditure on 'other' category |
| PCA | Principal component analysis |
| QC | Canadian province of Québec |
| Recyc | Expenditure on operation of recycling facilities |
| SWRMS | Solid waste resource management strategy (in Nova Scotia) |
| TF | Tipping (disposal) fee |

diversion rate (Goodick, 2002; Richter, Bruce, et al., 2017; Richter, Ng, & Bolingbroke, 2017; Wagner & Arnold, 2008; Walker et al., 2004; Wendt, 2001).

Walker et al. (2004) used the Genuine Progress Index to assess the costs and benefits related to NS's Solid Waste Resource Management Strategy (SWRMS). They found that the actual implementation of the SWRMS led to a per capita cost increase from $53/capita to $77/capita between 1997 and 2001, in constant 2000 Canadian dollars ($C2000). However, the total benefits from the program were estimated to be $33–$178/capita after the implementation of the SWRMS, considering environmental and economic benefits. Walker et al. (2004) also found that, on a regional level, the average disposal cost/tonne (in $C2000) for 1st generation landfills (without engineering controls) was approximately $36/tonne, while the cost for 2nd generation landfills (with engineering controls) was approximately $71/tonne, and the cost for transfer of waste to other disposal facilities was about $51/tonne.

Richter, Bruce, et al. (2017) used linear regression to investigate how various business and industry factors may be related to diversion rates in NS, ON, QC, and CA. In their study, they found that spending less than $250/tonne of waste managed was not effective in raising diversion rates in CA. They also concluded that NS focused on improving diversion rates, whereas other areas seemed to focus on lowered or minimized costs. The difference in allocation of resources may have allowed NS to invest in more sophisticated technologies which may have helped to increase diversion rate (Richter, Bruce, et al., 2017). Richter, Ng, et al. (2017) found that expenditure on post closure maintenance of disposal sites may have had a negative effect on diversion rates in certain regions in Nova Scotia. For example, the Cape Breton Regional Municipality had a diversion rate of 34% and had estimated post closure maintenance at CAD$41.2M for landfills within the region, compared to the Colchester County region, which had a residential diversion rate of 62.6%, but only had an estimated post closure maintenance fee for landfill in the municipality of CAD$12.1M.

Few studies are available on non-hazardous waste management expenditure in Canada (Lakhan, 2016; Richter, Bruce, et al., 2017; Wagner & Arnold, 2008; Walker et al., 2004). Most of these studies discuss absolute expenditure on select parameters, however, they failed to look at the percentage allocation of the entire budget on various parameters in the waste management system, and its relationship to diversion rate. Analysis using constant 2014 Canadian dollars per capita was carried out in this study to examine allocation of resources with respect to solid waste management. Interpretation of results was difficult due to increasing expenditure and fluctuations in economic performance, and as a result, percentage expenditure was chosen as a better indicator. Using percentage of expenditure as a relative contribution compared to the entire operating budget is a novel and interesting approach, which may provide insights related to optimal budget allocation for Canadian waste management systems. As well, most studies presented in Table 1 on expenditure use a small subset of data, for example, surveys of a subset of the population, phone interviews, or local data. This study, however, used percentage allocation of budget from provincial data and diversion rates. The objectives of this study are to (i) develop Multiple Linear Regression (MLR) models for each area (NS, QC, ON, and CA) using forward stepwise regression (FSR) and principal component analysis (PCA) with data on diversion rates and percent expenditure on 6 areas: collection & transportation (C&T), tipping fees (TFs), operation of disposal (Disp.), recycling (Recyc.) and organics processing (Org.), and other (Oth.) expenditure areas, and ii) to investigate how varying percentage allocation of resources, at the provincial level, affects diversion nationally and in 3 Canadian provinces.

## 2. Materials and methods

### 2.1. Data source

Data for this study was collected from Statistics Canada, a federal agency tasked with producing statistics on Canadian trends in population, resources, economy, society, and culture. Waste management data from 1996 to 2014 was collected, consolidated, and verified from 8 biennial Waste Management Industry Surveys (Statistics Canada, 1999, 2000, 2003, 2004, 2007, 2008, 2010, 2013), and 4 CANSIM tables (2017a, 2017b, 2017c, 2017d).

In Canada, waste data is collected via survey biennially. The survey gathers information on financial characteristics and waste management activities undertaken by both public and private sectors. Surveys collect data for one fiscal year, for example, in 2010, data was gathered between April 1st, 2010 and March 31st, 2011. In 2010, 1353 businesses and local governments were surveyed, and 1054 (78%) were fully or partially completed, and an additional 231 (17%) were considered in-scope, equating to a response rate of 95% (Statistics Canada, 2013). Due to the nature of the waste management industry in Canada, only waste and diverted materials that have been collected, processed, and disposed by either local governments or private waste management firms are included in the survey results collected by Statistics Canada. Any waste or diverted material that is managed directly by the generator is excluded from this study.

This study focuses solely on non-hazardous waste. Non-residential waste is generated by industrial, commercial, institutional, construction and demolition sources. Diversion is the quantity of material diverted from disposal facilities, the sum of all materials processed for recycling at an off-site recycling or composting facility. Current expenditure is broken up into 6 different categories by Statistics Canada, which include: Collection and Transportation (C&T), Tipping Fees (TF), Operation of Disposal Facilities (Disp.) Operation of Recycling Facilities (Recyc.), Operation of Organics Processing Facilities (Org.), and Other (Oth.). Collection and Transportation (C&T) is the cost associated with the collection and transportation of waste from the source to disposal facilities. Tipping Fees (also known as disposal fees) are fees paid to the owner, lessor, or operator of a landfill (or recycling, organic, or waste processing facility) for the right to dispose of waste within that landfill. These fees may be assessed on a weight, volume, or per item basis (Statistics Canada, 2013). Operation of disposal, recycling, and organics processing facilities are the expenditure related to the operation of any of these facilities. The 'other' category broadly encompasses any expenditure that does not fit into the 5 previous categories. For example, contributions to landfill post closure and maintenance funds were reported as part of the 'other' category prior to 2008 (Statistics Canada,