Analysis and Comparison of Solid Waste Management Systems and Diversion Practices in Alberta and British Columbia

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ABSTRACT

In this study, the solid waste management systems in Alberta and British Columbia are analyzed and compared. Geographically, Alberta and British Columbia are located side by side in Western Canada. These two provinces were selected and compared with respect to the non-hazardous waste generation characteristics and diversion practices. The municipal solid waste data were collected from Statistic Canada from 1996 to 2010. On average, about 1,464 samples were reported in the survey year from both of the business and the government sectors. The waste data was verified and processed for analyses. It was found that both in Alberta and British Columbia the non-residential waste generation is considerably higher than the residential waste generation during the study period. It is also found that the average family income per capita has shown a positive relation with the residential waste generation per capita in both provinces. Gross domestic product per capita has a positive relationship with the non-residential waste generation per capita in Alberta and British Columbia. With respect to waste diversion practices, it is found that the British Columbia system is much more effective than the Alberta system. From 1996 to 2010, the average waste diversion rate in British Columbia was 30.6% and in Alberta it was about was 14.5%. Despite of the fact that Alberta generated 50.9% more non-residential waste per capita than British Columbia, it spent only 18.3% more money in

the business sector of waste management. The waste management policies in the provinces are also discussed. Linear models of total waste generation, generation of residential and non-residential waste per capita and diversion rate of residential and non-residential wastes are proposed in this study.

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1. INTRODUCTION

1.1 Solid Waste Management

Solid waste is defined as the unwanted, unnecessary and unusable solid materials which are generated from various sources and activities. Solid waste is generally classified depending on the origin, engineering properties or potential hazards. According to the origin or source, solid waste can be classified as residential, industrial, commercial, construction or institutional waste. Similarly, it can be categorized using the waste composition such as organic, inorganic, glass, metal, plastic, paper, etc. In addition, solid waste may be classified according to the hazard potential, such as toxic, flammable, radioactive, infectious, etc. Management of solid waste is of great importance to our society. Proper management of solid waste reduces or eliminates adverse impacts on the environment and human health, supports economic growth and improves the quality of life. Numerous processes are involved in an effective waste management for a community, which typically includes monitoring, collection, transport, processing, recycling and permanent land disposal of solid waste.

1.2 Historical Overview

Humans and animals have been utilizing different types of resources on earth for their survival and throw away wastes since the ancient days. As the population on our planet was small and the land was abundant in the past, land disposal was not considered as an environmental or social problem. However, when people started to live in tribes, to form communities and villages, the enormous amount of waste generated was astonishing. The

accumulation of wastes had become a consequence of life and a significant social, economic and environmental problem.

Traditionally, littering and throwing of food and other organic wastes into the open areas led to breeding of rodents which caused the epidemic of plague. Plague was the result of inadequate solid waste management and poor personal hygiene practices. About half of the fourteenth-century Europeans were killed and it caused many subsequent life taking epidemics. In the nineteenth century, proper public health control measures were taken care of properly, particularly in solid waste management. People became conscious about the food wastes and other types of hazardous materials and realized that wastes must be collected and disposed of in a healthy and safe manner to minimize human and environmental risks. The public health and solid waste management is related because poor waste storage, collection, and disposal in open dumps cause breeding of rats, flies and other disease vectors. According to a study by U.S Public Health Service, the key reason for 22 human diseases is improper solid waste management practice.

1.3 Sources of Solid Waste

The management of solid waste generally depends on the origin, quality and the quantity of the specific waste. Solid waste is generated continuously 24 hours a day across the globe from various extraction, production, distribution and consumption activities. In this study, only non-hazardous waste is considered. The two main sources of non-hazardous solid waste in Canada are as follows:

i) *Residential Wastes*: This type of waste generates from primary and seasonal dwellings, which include all single family, multi-family, high-rise and low-rise residences.

ii) *Non Residential Wastes*: These wastes include all types of construction, renovation and demolition materials such as steel, stone, wood, concrete, brick, metal, cardboard, doors, windows, wiring, rubble etc. Different types of manufacturing industry and also commercial and institutional places are potential sources of solid waste generation. Shopping centres, restaurants and offices are major commercial sources whereas schools, colleges, universities, hospitals, government and non-government facilities are common institutional sources of solid waste generation (ECO Canada, 2010).

1.4 Environmental Impacts of Poor Solid Waste Management

Inappropriate disposal of solid wastes and inadequate or incomplete management system of recyclables or reusable wastes cause adverse impacts on environment. Improper design, operation, or maintenance of disposal sites, garbage dumps and other waste management facilities are another reason for these adverse impacts, as listed below (Chandrappa and Das, 2012; Haster and Harrison, 2002):

- **Risk to Public Health**: Rotten organic materials in poorly managed solid waste facilities create great public health risks. These rotten materials act as breeding grounds for various disease vectors which may cause many different diseases to human. Children and infants are especially vulnerable to these diseases. The situation is elevated when human or animal excreta or medical wastes are presented in the waste stream.
- **Property Damage:** The accumulation of uncollected solid wastes along streets can cause drain clogging which may create localized flooding and damage property and other infrastructures. Poor-designed or improperly-operated landfills

or open dumps near slums are susceptible to fire, causing great damages to public properties and serious threats to human and animal life.

- **Air Pollution:** Throwing decomposable wastes into landfills or other deep disposal sites leads to the production of methane gas under anaerobic degradation conditions. Methane gas from landfills represents a source of greenhouse gas emissions in Canada and contributes to global warming issues. Burning of garbage in residential areas and in landfills with the intention to reduce waste volume creates thick smoke containing carbon monoxide and nitrogen oxide. Both of these oxides are harmful to public and cause major degradation to air quality. Improper burning of polyvinyl chlorides (PVCs) also creates highly carcinogenic compound known as dioxins and contributes to air pollution.
- **Water Pollution**: Leachate from landfill is one the key concerns for surface and ground water contamination. Leachate generated from the decomposition of solid wastes introduces toxic materials and pathogenic organisms our water sources. Unlined landfills or improperly designed lining system are currently one of the key sources of ground water and surface water contamination in North America.
- **Destroying ecosystems**: To preserve sound ecosystem, proper solid waste management is necessary. Improper handling of solid waste such as dumping waste materials into rivers, ponds or other water bodies can make disturbance to aquatic habitats or other environmental sensitive areas, endangering native plants and animals. The waste particles may settles over time and changes the stream flow behaviors. Poorly maintained landfills in sensitive ecosystems can also make significant damage to valuable natural resources.

- **Damaging Economy:** Improper waste management and poor disposal of waste can cause damaging to economy. Tourism, which is one of the important parts of building a good economy of a modern nation, can be damaged by poor waste management. Uncontrolled solid waste disposal and unattractive piles of solid waste create unpleasant odor which discourage tourist activities. It adversely affects the establishment of local businesses and a healthy economy as well.

1.5 Integrated Solid Waste Management

Integrated Solid Waste Management (ISWM) is a widespread concept which comprises three major activities shown in Figure 1.1. These are:

i) Waste Prevention

ii) Recycling and Composting

iii) Disposal (Landfilling and Combustion)

Special actions such as careful planning, financing, collection and transport are required for each of these activities. The main goal of an effective ISWM system is to find out the best way to reduce and manage solid waste so that the human health and the environment can be protected in the most effective manner.

Figure 1.1: Components of Integrated Solid Waste Management

Integrated Solid Waste Management is a smart methodology which is aiming to create sustainable systems for human beings and also for the environment that are economically affordable, socially suitable and environmentally effective. This system typically involves the considerations of different management options. The options should be assessed independently and the best options should be implemented with respect to the specific needs of the community.

1.5.1 Waste Prevention

This strategy aims to prevent waste materials from being generated, which is also known as “source reduction”. This can be generally accomplished by reusing of products and materials, using less packaging materials and also by designing longer lasting products.

1.5.2 Waste Recycling and Composting

Recycling is a process to make new materials or products from certain waste materials such as glass, metal, paper, and plastic. Recycling generally involves collecting, reprocessing, and/or recovering process. On the other hand, composting is the process of conversion of organic waste materials into soil additives. Organic materials are rich in nutrients, which are beneficial in soil quality improvement. Several environmental and economic benefits can be accomplished by recycling and composting, such as reducing greenhouse gas emissions, decreasing the number of landfills and combustion facilities, creating new jobs and income sources, supplying valuable raw materials to different industries, etc.

1.5.3 Disposal (Landfilling and Combustion)

Landfilling and combustion are used to manage waste materials that cannot be recycled or be reused. Landfilling, by definition, is the permanent land disposal of solid waste in a properly designed, constructed, and maintained facility. Energy can be generated by recovering the flammable methane gas from landfills under anaerobic condition. Combustion of waste, also known as incineration, is a controlled burning process of waste materials to reduce waste volume and the associated risks. This process can also be used to generate electricity as the combustion process produce considerable amount of heat.

1.6 Waste Management in Alberta and British Columbia

Canada is an industrialised and well developed country in North America. It is the second largest country in the world (with respect to land area) and the total land area of Canada is 9,984,670 km² (Natural Resources Canada, 2005). The population density in 2005 is about 3.14 per km². The waste generation rate in Canada was about 965 kg/capita in the year 2010 (WMIS, 2013). It is among one of the biggest solid waste producing country in the world. In 2010, Canada generated about 32,947,000 tonnes of solid waste while fourteen years back, in 1996, Canada generated about 26,078,000 tonnes of solid wastes (WMIS, 2000; WMIS, 2013). It is interesting to note that, in fourteen years, the increase in solid waste generation was about 20.9%, which is extremely alarming. It is found that very few research studies have been conducted on solid waste management in Canada (Asase et al., 2009; Asha and Ng, 2015; Matsuto and Ham, 1990; Sawell et al., 1997; Wang et al., 2015).

The rates of generation, disposal or recycling are quite different in different parts of Canada. It is found that solid waste management in Canada, particularly western Canada, is poorly understood and documented. In this work, solid waste management system of two provinces of Western Canada are analysed and discussed.

Alberta and British Columbia are selected in this study, as shown in Figure 1.2. In the year 2010, Alberta and British Columbia generated about 8,745,000 tonnes of solid waste, which was more than a quarter (26.6%) of the total waste generated in Canada. British Columbia and Alberta are the fifth and sixth largest provinces in Canada, respectively. Geographically, the provinces are located side by side. Despite of their locations, it is found that there are some major differences in solid waste management systems in these provinces. Preliminary study suggested that the waste management system in British Columbia is more effective than the Alberta system. As such, waste management systems in these two provinces are compared and investigated to identify the reasons behind the differences. The ultimate goal of this research work is to implement the identified techniques or features in these systems to improve the overall performance Canadian solid waste management system. The objective of this study is:

- To examine and compare the solid waste generation characteristics in Alberta and British Columbia
- To propose simple linear models on the non-hazardous waste generation rates
- To identify the social-economic factors on waste generation rates in the provinces using regression analysis
- To investigate the waste diversion practices and make recommendations to current solid waste management system in the provinces

Figure 1.2: Map of Alberta and British Columbia (Website of Chevron in Canada)

2. LITERATURE REVIEW

Similar to other industrial nations, solid waste management is an important and challenging issue in Canada. The primary concerns of municipal solid waste management are the protection of human, resources conservation and reduction of environmental burdens (McDougall and Hruska, 2000). However, Canada, similar to most of the developed countries, human safety is not the primary driving force of solid waste management. Rather, the conservation of resources is a primary concern of waste management system (Wilson, 2007). To deal with the population growth and the increasing waste generation rate, solid waste management has become one of the biggest challenges in the world. It is found that more studies have been published on solid waste management in developing countries (Kumar et al., 2009; Marshall and Farahbakhsh, 2013; Ngoc and Schnitzer, 2009). The reason behind it might be, compared to developed nations, solid waste management practices and regulations in developing countries are much behind (Asase et al., 2009; Aziz et al., 2011; Talyan et al., 2008).

2.1 Waste Generation Rates and Factors in Different Countries

Waste generation rates are quite different in different countries. Different factors on waste generation rate have been suggested and reported by researchers. In China, urban development and energy consumption played a vital role in generation of solid waste.

However, according to Liu and Wu (2010), there was no direct relationship between the generation rate of solid waste and the Gross Domestic Product (GDP) as it was always thought to be in China. Another study conducted in Beijing, the capital city of China, revealed that both household size and income had a negative relation with the generation rate of solid waste; on the contrary, education level of the household had a positive relationship as families with higher education level produced more waste paper and plastic (Qu et al., 2009). Similar situation was observed in Ahvaz city, Iran, as low income household generated more wastes. In Ahvaz city, over 400 household samples were studied and it was found that, low income household generated more wastes (5.4 kg/HH•day) and family size and education level also had a relationship with the generation rate (Monavari et al., 2012).

Yet a different type of relationship was observed in Chittagong, Bangladesh. Sujauddin et al. (2008) conducted a study on waste generation rates in Rahman Nagar Residential Area, Chittagong. The study showed that, family size, education level and monthly income of the households were positively related to the waste generation rate, with the generation rate estimated to 0.25 kg/person•day (2008).

Qdais et al. (1997) reported that socioeconomic level was a key factor of waste generation rate in Abu Dhabi. However, the sample size of their study was very limited. The study involved 40 houses with different socioeconomic levels and 840 waste samples. The study estimated that, the average waste generation rate in Abu Dhabi was 1.76 kg/person•day. According to their study, the rate was dependent on the income level with an increase of about 35% for the high income residents over the average rate.

A study on municipal solid waste generation reported that high income countries produced one-quarter of the world's MSW, but accounted for only one-sixth of the world's population (Beede and Bloom, 1995). Unfortunately, not so much research work related to waste generation in North America was found, especially with respect to Canada. A study was conducted by Mosler et al. (2006) in Santiago de Cuba on solid waste generation and treatment. About 1,180 households were studied and the result showed that waste generation did not increase with higher income level. However, Mosler et al. (2006) suggested that generation rate and the income level are likely to be positively correlated at national level. In United States, the generation rate of solid waste was 2.09 kg/capita•day (USEPA 2009) and in Canada, it was 2.64 kg/person•day (WMIS, 2013).

Table 2.1 shows the generation rate of solid waste in different countries in the world. Only recent studies (1997-2015) were considered in this study. It was observed that per capita solid waste generation rate is higher in developed countries than in developing countries. Education level, household income and family size are possible factors behind the solid waste generation in developing countries. However, the social and economic factors on waste generation in developed countries in North America such as United States and Canada are poorly understood due to limited amount of published work.

Table 2.1: Recent Studies on Waste Generation Rates in Different Countries

Country	Generation rate (kg/capita•day)	Remarks	References
Cuba (Santiago de Cuba)	0.09	A survey was conducted covering 1,180 households in February, 2004. This is residential waste generation rate.	Mosler et al., 2006
China (Beijing)	0.23	The data was collected from 1985 to 2006 provided by State Statistical Bureau, P.R. China. This is total waste regeneration rate.	Liu and Wu, 2010
India (Delhi)	0.50	The data was published by a Government agency of India. This is total waste generation rate.	Talyan et al., 2008
Iran (Mashhad City)	0.61	Several questionnaires were prepared and distributed among various branches of the municipality, other related organizations such as the Mashhad composting plant and various sectors of the population (2,220 among the population, 100 among municipality staff, 20 among composting plant workers, 76 among hospital workers and 450 among industrial units). This is total waste generation rate.	Farzadkia et al., 2012
Iraq (Erbil)	0.65	The survey was conducted among the households of Erbil for about one year. This is residential waste generation rate.	Aziz et al., 2011
Cambodia (Phnom Penh)	0.74	The data was collected from JICA research studies. This is total waste generation rate.	Seng et al., 2010
Portugal	1.32	The study was primarily based on the national inquiry carried out in 2003. This is total waste generation rate.	Magrinho et al., 2006
U.A.E (Abu Dhabi)	1.76	The survey covered 40 houses with different socioeconomic levels and total 840 samples. This is residential waste generation rate.	Qdais et al., 1997
USA	2.09	A materials flow methodology was used that relies on a mass balance approach. This is total waste generation rate.	USEPA, 2009
Canada	2.64	The data was collected from a survey. Survey questionnaires were mailed to a total of 1,353 businesses and local governments related to waste management in Canada. This is total waste generation rate.	WMIS, 2013

2.2 The Roles of the Public and Private Sectors on Waste Management

As discussed, recycling is a major component of integrated solid waste management system. Generally, collection, transportation and management of municipal solid waste are very poor in developing countries. For instance, in India, about 90% of MSW was disposed unscientifically in open dumps and landfills, creating problems to public health and the environment (Sharholy et al., 2008). According to Talyan et al. (2008), in Delhi, the capital city of India, only 70-80% of the total MSW generated was collected and the rest remained in the street untreated. Only 9% of the collected wastes were managed using composting technology, and the remaining 91% were dumped into uncontrolled open landfills (Talyan et al., 2008). Similar situation was observed in Dar es Salaam, the capital of Tanzania, Africa. In the year 1991, the daily waste generated in Dar es Salaam was about 1,400 tonnes, from which only 5% was collected. However, in the year the research was conducted, the total waste generation was over 2,500 tonnes and the collection was about 48% (Kassim and Ali, 2006).

The collection, transportation and disposal of municipal solid waste were also found to be inadequate in Erbil, Iraq. Aziz et al. (2011) suggested that the government should have taken necessary steps and increased the budget to improve the system. A deeper involvement of governmental agencies on solid waste management issues such as policy changes and implementation of pay-as-you-throw programs is often suggested by researchers. For example, Sujauddin et al. (2008) stated that the situation of waste management in Rahman Nagar Residential Area in Chittagong was beyond handling by the municipality. The local residents was found to take service from local waste management authorities and about 44% of respondents of the survey reported that they

were willing to pay $0.3 to $0.4 dollars per month to the waste collectors. The local residents also demanded that the service charge would be based on the volume of the wastes.

The privatization issues of solid waste management services was investigated and reported in a number of studies. In Kampala, the capital of Uganda, it was observed that, the private sector was more capable than the public sector, while public sector served the low income groups and the private sector served the high income groups. However, both the services were hampered by corruption and ambiguity (Katusiimeh et al., 2012). A number of studies suggested that a three-way partnership was needed among private sector, public sector and citizens for an effective solid waste management system. To form this type of partnership, a facilitating agency is recommended (Ahmed and Ali, 2006; Sujauddin et al., 2008; Talyan et al., 2008). In Dar es Salaam, Tanzania, the solid waste collection service by the private sector was deeply influenced by household's attitudes and behavior (Kassim and Ali, 2006). One study, conducted in Yaoundé, Cameroon, showed that, distances and lack of infrastructures had a major impact on waste collection (Parrot et al., 2008). Asase et al. (2009) compared the solid waste management systems in London, Ontario and Kumasi, Ghana and showed that the sustainability concept used in London would be equally applicable in Kumasi, Ghana.

2.3 Waste Recycling and Diversion Rates

Due to the scarcity of available land area, recycling is considered as a better alternative than landfilling. All over the world, the interest in recycling is growing rapidly. For instance, in Mashhad city, Iran, the amount of recycled solid waste was increased from 2.42% (2,588 ton/year) in 1999 to 7.22% (10,165 ton/year) in 2008 (Farzadkia et al.,

2012). Similar results were observed in Haulien County in Taiwan. The recycling rate was 6.8% in 2001, and increased to 32.4% in the year 2010, and it would be increased steadily by 2-5% yearly in the near future (Chang et al., 2013).

Menikpura et al. (2013) conducted a study in Nothabari municipality, Thailand and showed that recycling practices contribute to the overall sustainability by improving the social, economic and environmental sustainability. They reported that 24% recycling rate balanced the negative impacts on social, environmental and economic loss. Not all of the countries enjoy a high diversion rates. For example, in Lagos, Nigeria, recycling was in the early stage and it was about 1.1% (Kofoworola, 2007). In Portugal, the recycling rate was about 11.0% (Magrinho et al., 2006) and in Phnom Penh, Cambodia, it was about 9.3% (Seng et al., 2010).

According to Sawell et al. (1997), in Canada, about 83.9% of all residential and non-residential wastes went to landfills, 16.1% was recycled in 1992. According to WMIS (2013), the recycling rate in Canada was 24.5% in 2010.

3. METHODOLOGY

This study attempts to find out the differences of solid waste management systems between Alberta and British Columbia and the reasons behind them. There are very limited studies on solid waste management in Canada (Asase et al., 2009; Sawell et al., 1997). Waste data are collected from Statistics Canada's Solid Waste Management Surveys: Business and Government Sectors (WMIS, 1999; WMIS, 2000; WMIS, 2003; WMIS, 2004; WMIS, 2007; WMIS, 2008; WMIS, 2010; WMIS, 2013). Statistics Canada, found in 1971, is the Canadian federal government agency commissioned with producing statistics to help better understand Canada, its population, resources, economy, society and culture (Statcan, 2010). Statistics Canada has systematically collected data on solid waste management in Canada for more than 20 years. Data from the reports are analyzed and examined to study solid waste management systems of Alberta and British Columbia. In this research, the selected study period is from 1996 to 2010 due to the availability of the data. The Waste Management Industry Surveys are biennial surveys. The information on total revenues, total operating and capital expenditures, total employment and waste quantities were also collected.

3.1 Data Collecting and Processing

The solid waste management surveys were performed by Statistics Canada in two sectors: business sector and government sector. Survey questionnaires were mailed to an average of 1,464 businesses and local governments each survey year and the responses were returned by mail. Businesses were selected based on the size of their workforce, as well as the level of their total revenues. The smaller business firms, which were excluded from the survey study, their contributions to solid waste management industry were

quantified from Business Register of Statistics Canada. The questionnaires were addressed to the contact person who was responsible or had the knowledge about the waste management operation of the survey unit. For the businesses that had operations in more than one Canadian province, separate questionnaires were sent for each province in which they had operation of waste management. The follow ups were conducted by fax or telephone after the return due date to remind respondents to return their questionnaires. Furthermore, the collected data were checked in multiple stages to minimize inaccuracy. The respondents were asked to specify the amount of time they spent to complete the questionnaires. The time the respondents took to complete the questionnaires was ranged from 1.0 hour to 4.2 hours, with an average of 2.8 hours. Figure 3.1 shows the scope of the study.

The overall average response rate from the year 1996 to 2010 waste management industry surveys, based on the ratio of the number of completed and partially completed questionnaires to the total number of in-scope questionnaires, was 77.6% for the business sector and 89.6% for the government sector.

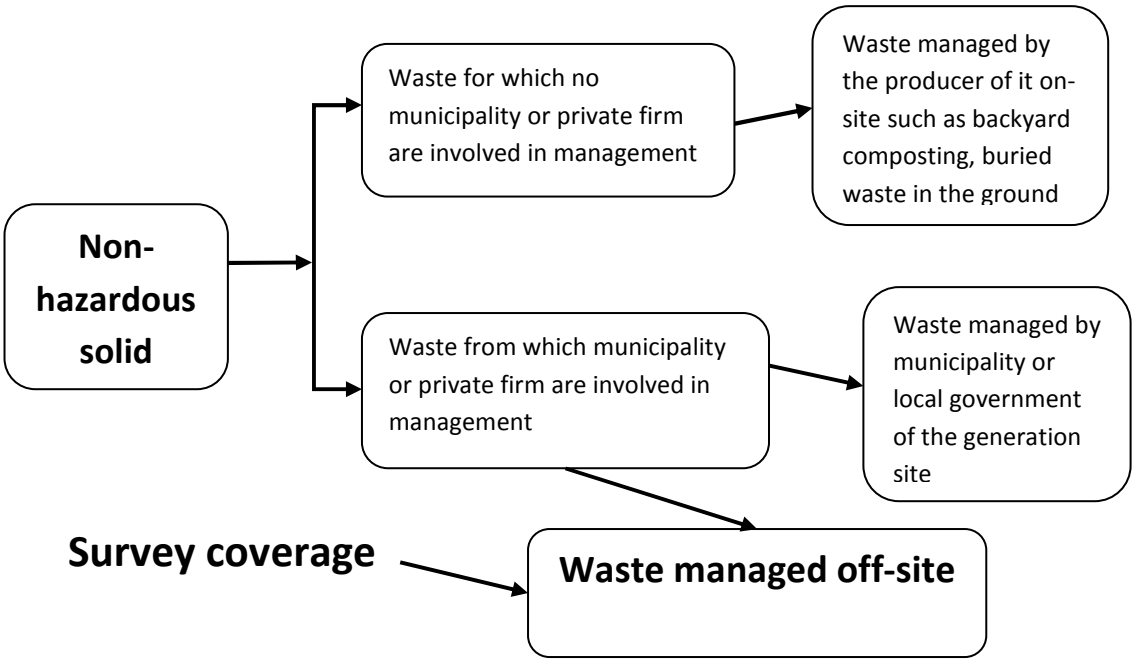

Figure 3.1: Waste management industry survey coverage (adapted from: WMIS 2013)

3.2 Data Verification and Accuracy

In this study, only revised data from the reports were used. For instance, in the survey report of 2006, the waste disposal per capita in Alberta was 1,133 kg per capita in the year 2006; however, according to the survey report 2008, it was 1,117 kg per capita. In this case, the data from the latest survey, which was conducted in the survey 2008, were taken. The revision was needed to avoid inaccuracy of the data. Furthermore, there were some discrepancies in the data. For instance, in Alberta, solid waste disposal per capita was 1,155 kg/person in the year 2008. However, if this disposal per capita was calculated from the total waste disposed (4,147,000 tonnes) and the population (3,433,000); the disposal per capita rate would be 1,208 kg/person. In the present study, the published data were used for consistency of data. If data for a given year were not available, then the derived data were used. Taken as a whole, the biennial rate of revision for the disposal and diversion quantity data at the national level had been less than 5% in each of the past three survey cycles. These data were revised by Statistics Canada Business Register and industry directories. In these surveys, all data were compared to the data of the previous years to ensure the accuracy and the consistency.

3.3 Waste Definitions and Scope

In this study, the following definitions were adopted from the WMIS reports:

- Residential waste includes solid waste which are generated in residents and picked up by the municipality to the transfer stations or to the landfills or to any other disposal facilities.

- Non-residential wastes include all wastes except residential wastes. These consist of industrial, commercial and institutional wastes (IC&I) and wastes from Construction and Demolition (C&D) such as wood, drywall, certain metals, cardboard, doors, windows, wiring and others. However, different types of materials from areas which were not developed previously and materials such as asphalt, brick, concrete or clean sand or gravels were not included in this category.

Wastes managed on site by the household or the company, were not considered in this study. Most of the residential wastes were handled by municipalities and the private businesses. It was assumed that a considerable amount of non-residential wastes were managed on site by the industrial generators. Furthermore, much waste was transported by the generator directly to the landfill, thus no private firm or local government was involved in it. In this study some other types of wastes were not included such as materials that were reused, materials that were collected through deposit-return systems and not processed at a material recovery facility (WMIS, 2013).

4. ANALYSIS AND DISCUSSION

Waste management is the process of collecting, processing and disposing of waste. In this study, two provinces in Western Canada were selected to study the non-hazardous solid waste generation characteristics using the data from 1996 to 2010; they are Alberta (AB) and British Columbia (BC). Both residential and non-residential wastes were considered in the present study. Differences in the waste management and waste diversion practices were examined to provide insights into solid waste management in Western Canada.

In this study two provinces are compared. Though it is a common practice to compare two cities on the basis of solid waste management, however, comparing two cities can be difficult due to limited data, or no available data in the case of smaller cities. In Western Canada, solid waste data is also difficult to access sometimes. Also there can be different waste definitions used in different cities. The benefit of provincial method is Statistics' Canada's data is reliable and representative due to the large samples (province instead of a city), and consistent methods. The data is also very accessible since it is available online, whereas many cities do not post historical waste data online (some only post 1-2 years of data). On the other hand, the inherent difficulty in comparing provinces is that waste policies vary significantly in different part of the provinces, and so does culture.

Alberta and British Columbia were selected because as they are located side-by-side geographically (Figure 1.2). The basic statistics of these provinces are shown in Table 4.1. Alberta and British Columbia covers almost 16.1% of the total area of Canada. As it is shown in Table 4.1, waste diversion rate is considerably higher in British Columbia than Alberta. Waste diversion is a method to prevent and reduce the waste by recycling, reuse or composting. Waste recycling contributes to environmental, financial and social benefits by conserving energy, reducing disposal costs and reducing the burden on landfills and other waste disposal methods.

Table 4.1: Features of Alberta and British Columbia (Data in 2008)

	Alberta (AB)	British Columbia (BC)
Total Land Area, km²	661,848	944,735
Proportion of Canada, %	6.6	9.5
Population	3,433,145	4,384,310
Population Density, population/km²	5.19	4.64
Gross Domestic Product (GDP) per Capita, $/person	84,198	42,099
Waste Diversion Rate, %	14.9	34.9

4.1 Waste Generation Characteristics

Figure 4.1 shows the generation rate of total non-hazardous wastes in Alberta and British Columbia. Total waste means the summation of residential and non-residential wastes. It is observed that, the generation of total wastes per capita per day in Alberta was higher than British Columbia from 1996 to 2010 except in the year 2002. In these fourteen years, the average waste generation rate in Alberta and British Columbia were 3.23 kg/capita•day and 2.47 kg/capita•day respectively.

The generation of non-residential wastes was higher than the residential wastes in both the provinces from 1996 to 2010, as it shown in Figure 4.2a. In Alberta, around 31% of total wastes generated are residential wastes and 69% are non-residential wastes and in British Columbia, about 40% are residential wastes and 60% are non-residential wastes. Both in Alberta and British Columbia, ratio of the generation of non-residential wastes and residential wastes are decreasing over the study period (Figure 4.2b).

$$Ratio = \frac{\left(non-residential\ \ waste\ \ generation\right)-\left(residential\ \ waste\ \ generation\right)}{residential\ \ waste\ \ generation}$$

In the year 1996, generation of residential waste was about 20.6% (620,000 tonnes) and generation of non-residential waste was 79.4% (2,387,000 tonnes) (WMIS, 1999), and in the year 2010, generation of residential waste was 28.1% (1,303,000 tonnes) and generation of non-residential waste was 71.9% (3,327,000 tonnes) (WMIS, 2013). On the other hand, in case of British Columbia, in the year 1996, the generation of residential waste was 30.5% (867,000 tonnes) and generation of non-residential waste was 69.5% (1,974,000 tonnes) (WMIS, 1999) and in the year 2010, generation of residential waste

was 43.9% (1,629,000 tonnes) and generation of non-residential waste was 56.1% (2,084,000 tonnes) (WMIS, 2013).

From Figure 4.2b, it is observed that the ratio of the non-residential waste and residential waste of Alberta and British Columbia is decreasing and for both the provinces, the decreasing rate is almost similar. The reason behind that might be the population growth rate for both the provinces is increasing with time. Increase in population rate leads to increase in the generation of residential wastes. Comparing to the increasing rate of population, the increasing rate of GDP is less which might have an impact on the generation of non-residential wastes.

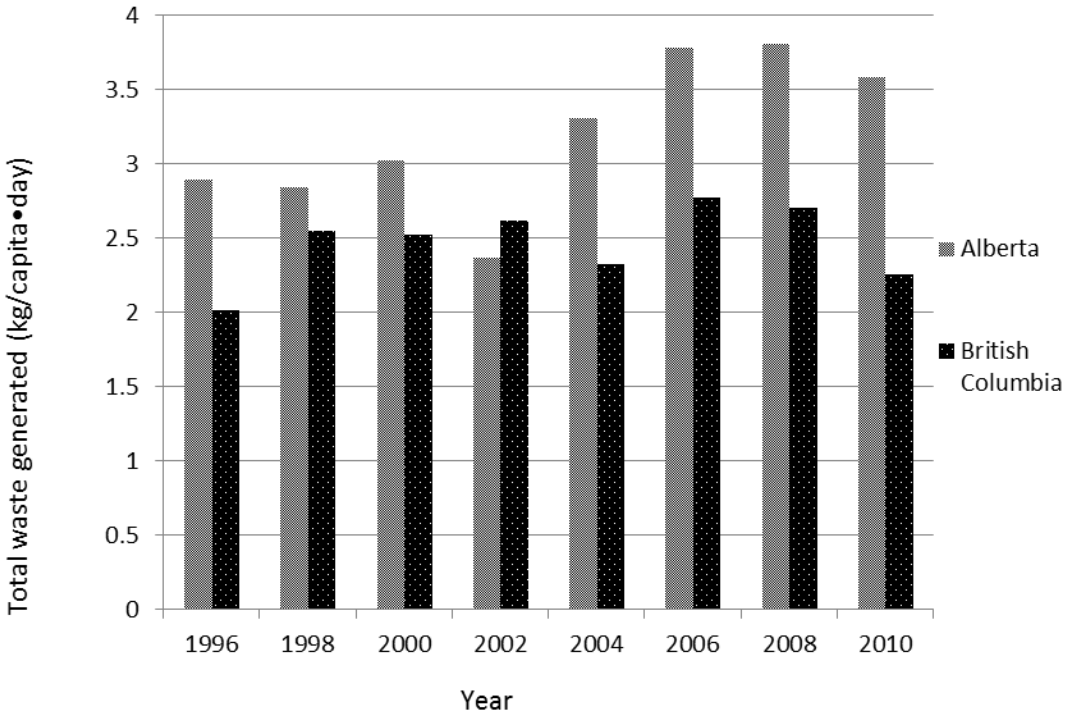

Figure 4.1: Generation of total non-hazardous waste per capita per day in Alberta and British Columbia

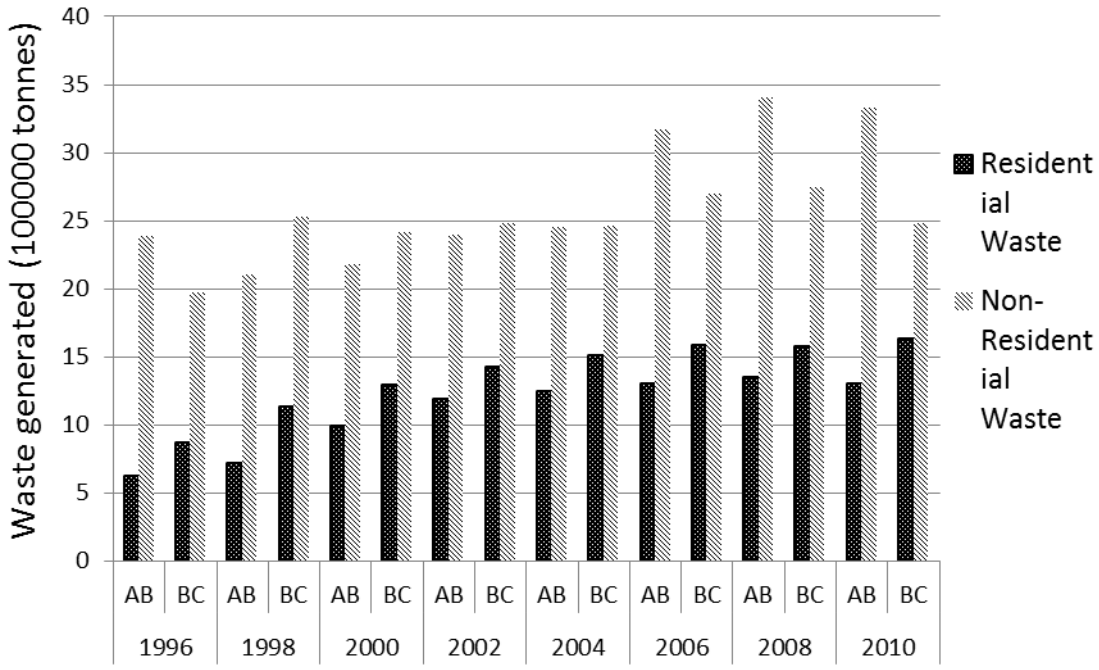

Figure 4.2a: Residential and non-residential wastes generated in Alberta and British Columbia

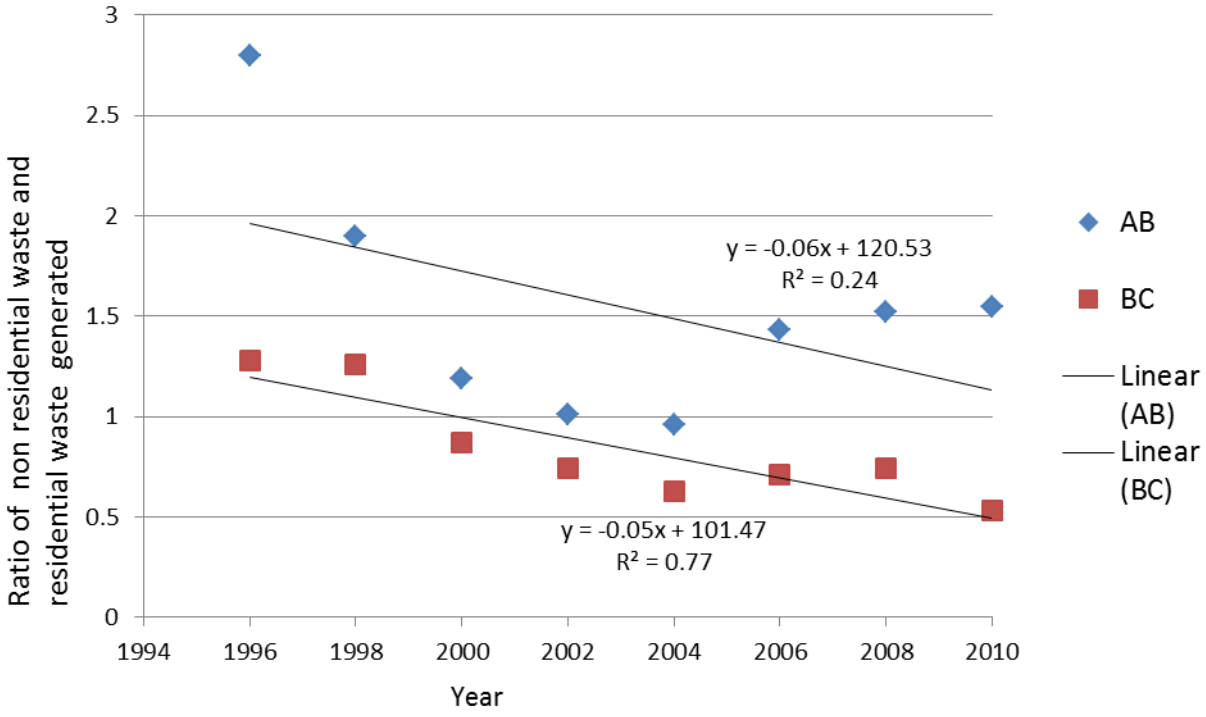

Figure 4.2b: Ratio of non-residential and residential waste generated in Alberta and British Columbia

4.1.1 Factors behind Generation of Residential Wastes

Residential waste includes solid waste generated in residential areas, and collected by the municipality for transport to transfer stations, landfills, or other disposal facilities. The average generation rates of residential wastes in Alberta and British Columbia in the last decade were 0.97 kg/capita•day and 0.91 kg/capita• day respectively, which are very similar. Socio-economic level is one of the key factors in generating residential wastes. According to some studies generation of residential wastes is related to the family income of the residents (Jadoon et al., 2013; Liu and Wu, 2010, Monavari et al., 2011, Ojeda-Benitez et al., 2008). On the other hand, some studies did not find that type of relationship (Badruddin et al., 2002; Li, 2009). A positive relation between the generation of residential waste and annual average family income is found in Alberta and British Columbia as it is perceived in Figure 4.3. It makes sense in the way that, as Canada is an economically developed country, if family income increases, it also increases the ability of a family to buy more household staffs which leads to the increase in the generation of residential wastes. Food wastes contribute the highest amount of residential wastes. Here the family income is expressed in the 2011 constant dollars (AMF income, 2013). 2011 constant dollar means the monetary value of Canadian dollar in the year 2011.

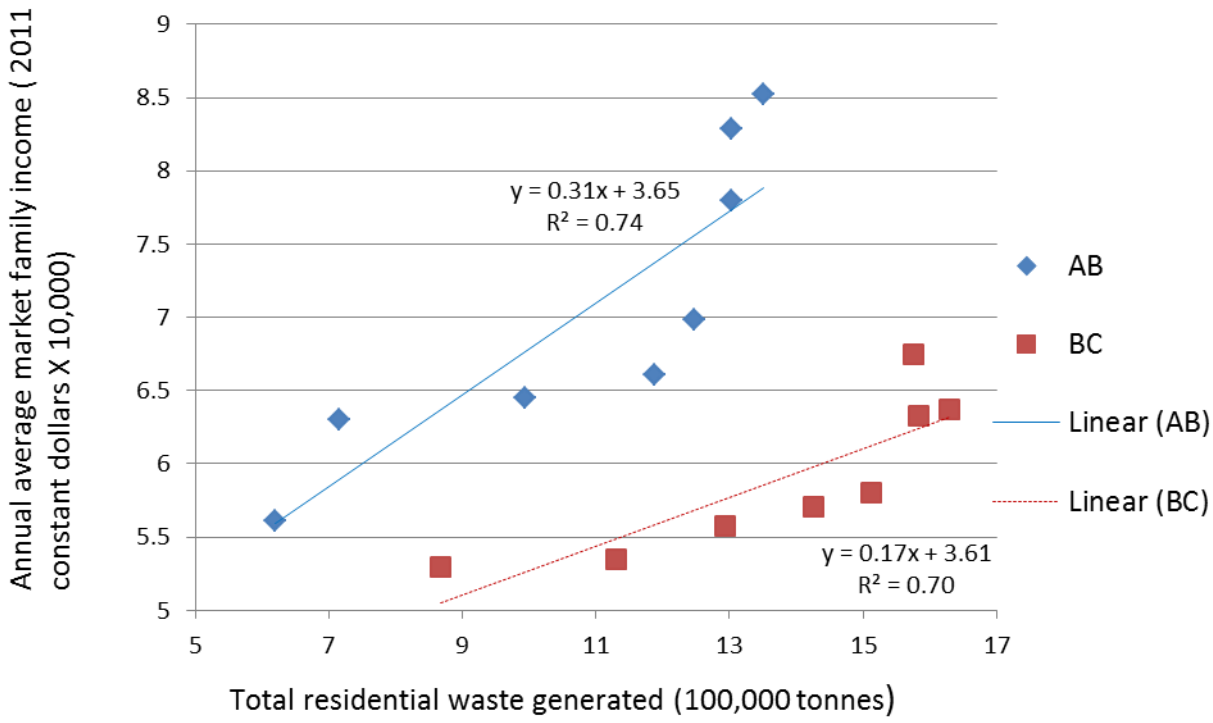

Figure 4.3: Relationship between total residential waste generated and annual average market family income in Alberta and British Columbia

4.1.2 Factors behind the Generation of Non-Residential Wastes

Non-residential waste includes all wastes except residential waste. These consist of Industrial, Commercial and Institutional wastes (IC&I), and wastes from Construction and Demolition (C&D) sources. C&D waste includes materials such as wood, drywall, certain metals, cardboard, doors, windows, wiring, and others. Different types of materials from previously undeveloped areas and materials such as asphalt, brick, concrete or clean sand or gravels were excluded from this category. The average generation rate of non-residential wastes are 2.26 kg/capita•day and 1.56 kg/capita•day in Alberta and British Columbia respectively from 1996 to 2010. Gross Domestic Product (GDP) is the monetary value of all the completed goods and services produced within a country in a specific time period calculated on an annual basis. It includes all private and public expenditure, government outlays, investments and exports less imports that take place within a defined region. In Figure 4.4, the relationship between the generation of non-residential waste and the GDP in Alberta and British Columbia (GDP, 2011) in the last fourteen years is shown. It is noticeable from the figure that, for both in Alberta and British Columbia, GDP is positively related to the generation of non-residential wastes. Alberta generated more non-residential wastes than British Columbia and the GDP of Alberta was way higher than that of British Columbia. Increase in industry contributes the increase of GDP and increase is industry takes along with more non-residential wastes. Alberta is endowed with energy and other resources that had got high global demand which lead to increase more energy related industry. Manufacturing industries also add to the generation of non-residential wastes. In the year 2010, manufacturing sales per capita in Alberta and British Columbia were $16,962 and $7,882 respectively

(Manufacturing Sales, 2015). Also in this case, it is observed that, manufacturing company in Alberta is larger than British Columbia.

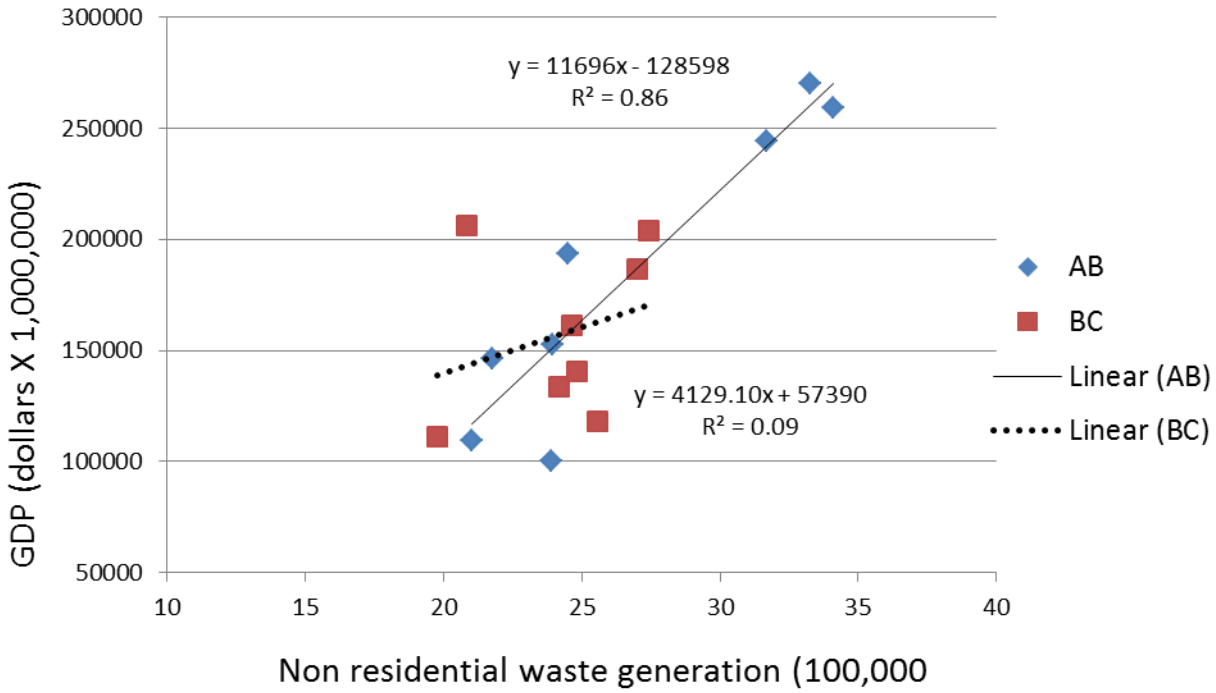

Figure 4.4: Relationship between the generation of non-residential waste and Gross Domestic Products in Alberta and British Columbia

4.2 Linear Waste Generation Model

A regression uses the historical relationship between an independent and a dependent variable to predict the future values of the dependent variable. Regression models can be either linear or nonlinear. A linear model assumes the relationships between variables are straight-line relationships, while a nonlinear model assumes the relationships between variables are represented by curved lines. There are several different classes of regression procedures, with each having varying degrees of complexity and explanatory power. The most basic type of regression is that of simple linear regression. A simple linear regression uses only one independent variable and it describes the relationship between the independent variable and dependent variable as a straight line. Here linear model is used for its simplicity and scientific acceptance.

In this section, linear models about residential, non-residential and total wastes generated in Alberta and British Columbia are proposed. In Figure 4.6, it is observed that, generation of total wastes is increasing with time both in Alberta and British Columbia. However in case of Alberta, it is increasing more rapidly and the growth is much higher than British Columbia. The R^2 value of the trend line of Alberta and British Columbia are 0.91 and 0.44 respectively. Comparing the R^2 values, British Columbia has a lesser linear trend than Alberta. The reason behind that might be there is a sudden jump in generation of total waste in Alberta from 2004 to 2006, and there is a fall in British Columbia from 2008 to 2010. In Alberta, from 2004 to 2006, the population growth rate increased from 2% to 6% and the average family income increased from $69,800 to $78,000. These facts might lead to the sudden jump of the generation total wastes in Alberta from 2004 to 2006. On the other hand, in British Columbia, the population growth rates were same

both in 2008 and 2010 and the average family income was a little bit higher in the year 2010 than in the year 2008. However, the growth of GDP was much lower in the year 2010 than in the year 2008. In 2008 the increase in GDP in British Columbia was 9.2% from the previous year, while in 2010, the increase in GDP was only 1.0% from 2008. This factor could play a vital role for the decrease of the generation of total wastes in British Columbia from 2008 to 2010. It is seen that, at the end of 2020, total waste generation in Alberta will be around 6,300,000 tonnes and in British Columbia, it will be around 4,900,000 tonnes, assuming all the factors remain the same.

The principal advantage of linear regression is its simplicity, interpretability, scientific acceptance and widespread availability. In this research linear regression was used to compare results to other studies (Qdais et al., 1997; Wang et al., 2015). Figure 4.7 demonstrates that, both in Alberta and British Columbia, per capita generation of residential waste is increasing. In Alberta, the increasing rate is slightly more than in British Columbia. According to this model, at the end of 2020, residential waste generation per capita in Alberta would be around 540 kg/person and in British Columbia it would be around 470 kg/person, if all factors remain same. In case of non-residential wastes as shown in Figure 4.8, it is observed that, the generation of non-residential waste in Alberta is increasing and on the other hand, in British Columbia it is almost steady over time. At the end of 2020, the non-residential waste generation per capita will be around 1,900 kg/person in Alberta and around 600 kg/person in British Columbia.

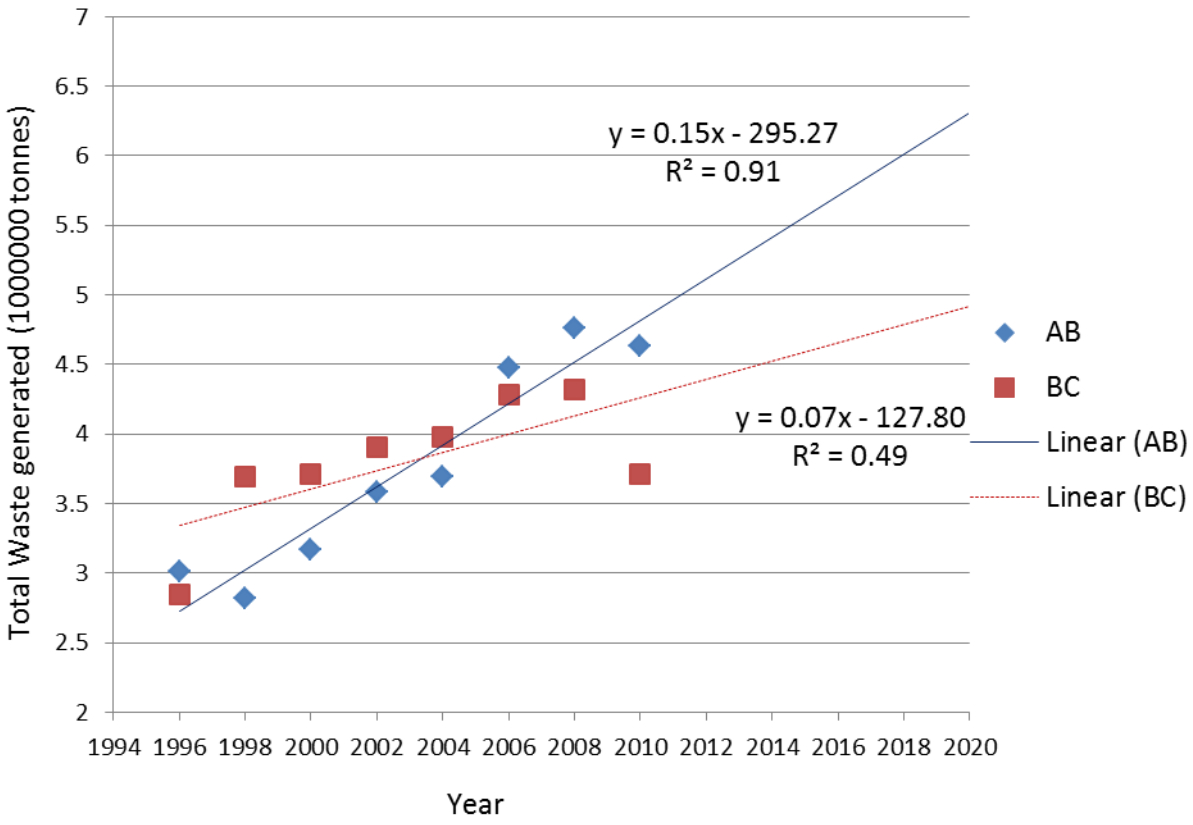

Figure 4.5: Linear model of total waste generated in Alberta and British Columbia

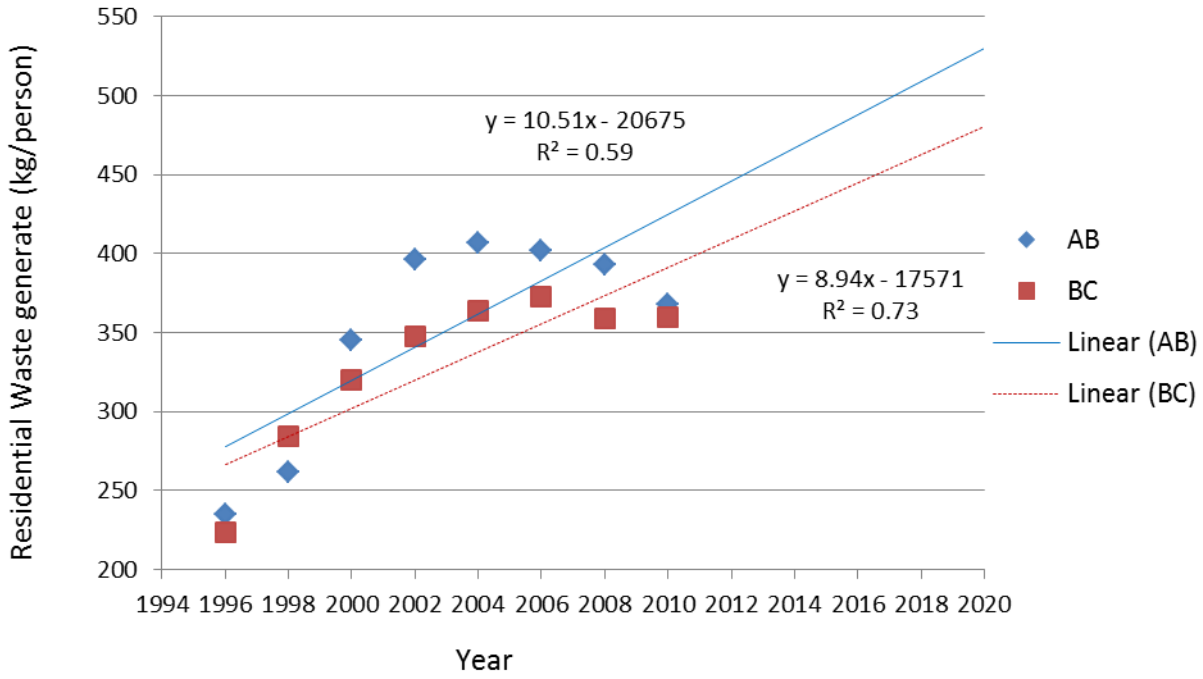

Figure 4.6: Linear model of residential waste generated per capita in Alberta and British Columbia

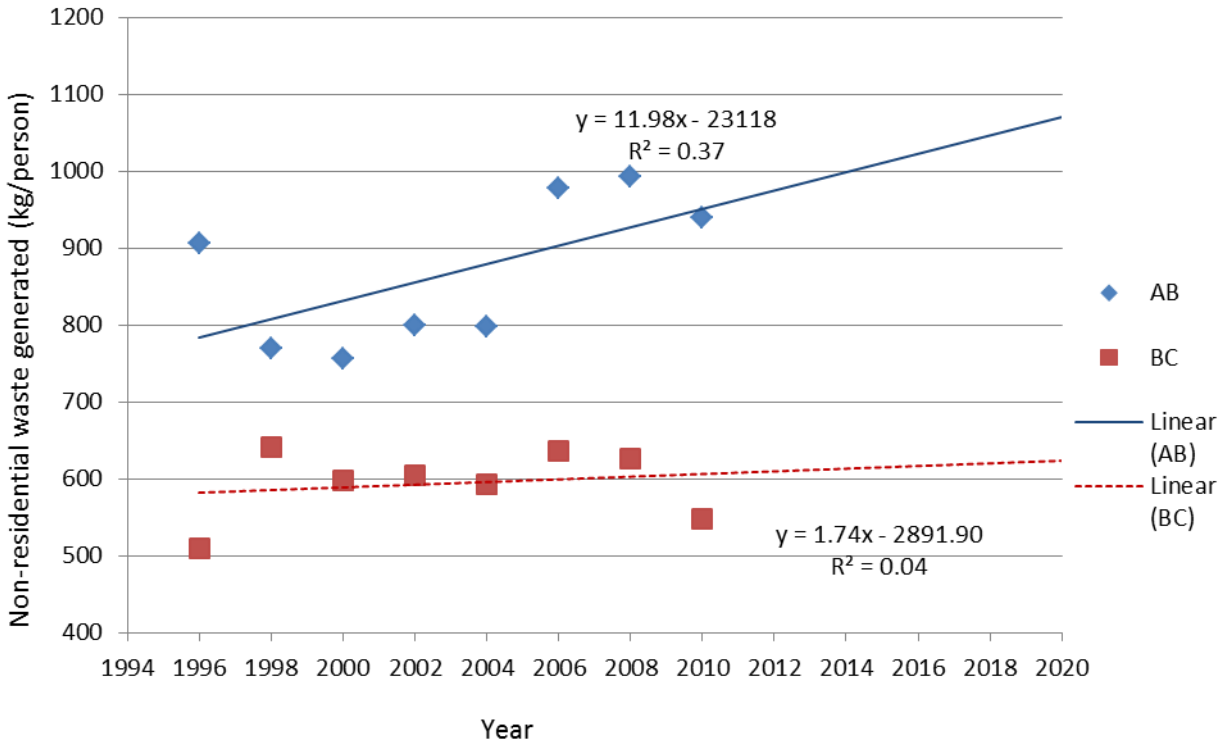

Figure 4.7: Linear model of non-residential waste generated per capita in Alberta and British Columbia

4.3 Waste Diversion

Waste diversion is the prevention and reduction of generated waste through source reduction, recycling, reuse, or composting. Waste diversion generates a host of environmental, financial, and social benefits, including conserving energy, reducing disposal costs, and reducing the burden on landfills and other waste disposal methods. Generated waste goes through different activities. Some are taken to landfills and are buried, some are composted, some are burnt and some are recycled. As landfills have a limited capacity, waste diversion is a very good way to deal with the solid wastes. Figure 4.8 shows the waste diversion rate in Alberta and British Columbia from 1996 to 2010. A waste diversion rate is the percentage of waste diverted out of the total amount of waste generated.

$$Waste\ \ diversion\ \ rate\ \ (\%) = \frac{Waste\ \ diverted}{Total\ \ waste\ \ generated} \times 100\%$$

From Figure 4.8, it is seen that from 1996 to 2010, British Columbia is doing a better job than Alberta in waste diversion. In Alberta, waste diversion rate was much lower than the national average and in British Columbia; the diversion rate was higher than the national average, except in the year 1996. The average waste diversion rate in Alberta is 14.50% and in British Columbia is 30.63% in the last decade. Many factors put impact on the diversion rates. Among them, according to some studies- expenditure and workforce can play a vital role (Aziz et al., 2011; Sujauddin et al., 2008).

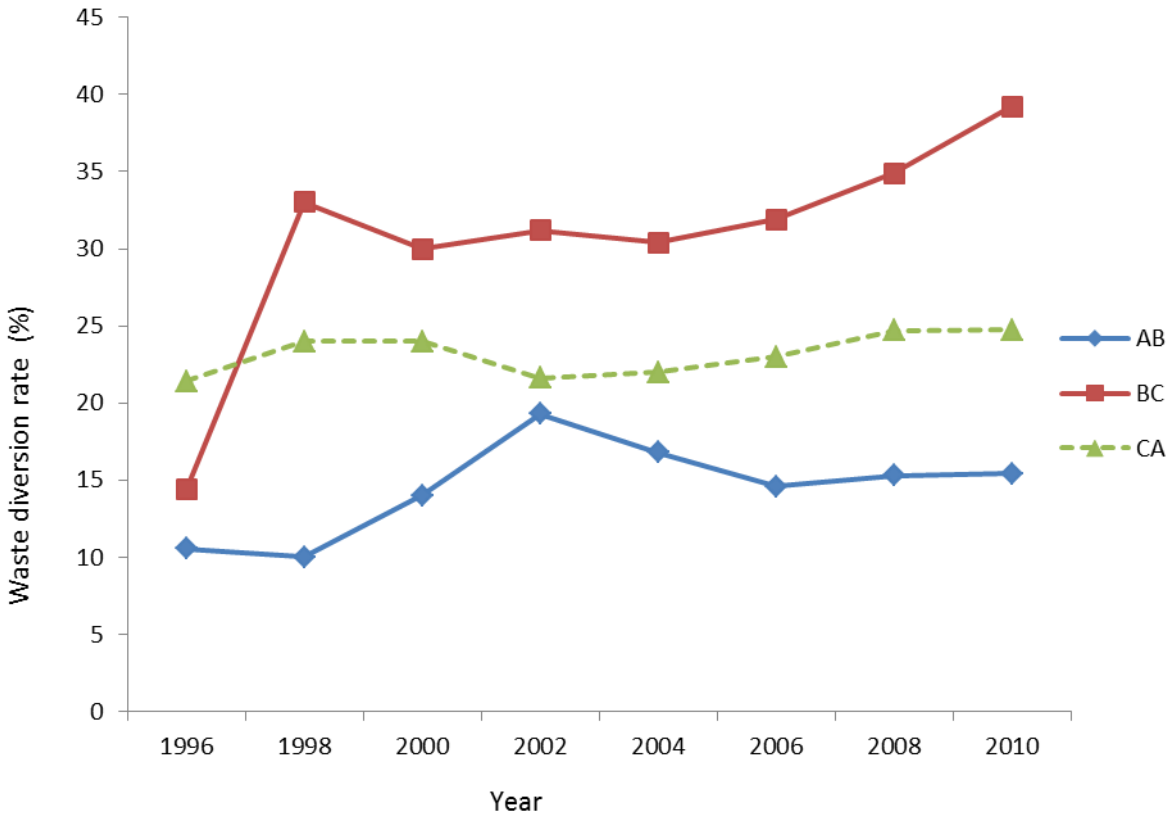

Figure 4.8: Waste diversion rate in Alberta and British Columbia

4.3.1 Policies in Waste Diversion

An overview of the policies about waste recycling in Alberta and British Columbia is shown in Table 4.2. It is observed that, almost all the policies are present in British Columbia. Curbside recycling is a popular system in recycling program. Curbside recycling has a great impact on recycling rates. Many municipalities across British Columbia offer curbside collection of garbage, recycling and organics. Accepted materials and preparation guidelines vary across municipal and regional boundaries. In some areas collection is provided by the city, in some areas by the regional district and others by private collection companies. In Alberta, not all cities have the facility of curb side recycling. Municipalities across Alberta have various methods for the collection of recyclables. Several options exist there, such as blue boxes, blue bags and recycling depots. Some programs require that you sort your recyclables in to "like" materials (e.g. paper, plastic, glass, etc.) while others collect all of the items together and then sort the materials at a recycling facility. In some cases recyclables are picked up through curbside collection programs and in other cases citizens need to take their recyclables to a selected location.

PAYT stands for pay-as-you-throw. It refers to a usage pricing for disposing of municipal solid wastes or sometimes simply “bag tags”. Users are charged on how much waste they present for collection to the municipality or local authority. In this system, generally, residential wastes are included. In British Columbia, PAYT system is better than the other provinces in Canada. British Columbia has a gradual reduction of about 15% residential waste in sending to landfill (Robins and Kellenher, 2005). Since the introduction of PAYT, there was an increase of waste diversion rate of about 38% from

15% in the Capital Regional District (CRD). However, city of Vancouver, BC, was the first large city in Canada to implement a variable can subscription system. Garbage, recycling and yard trimmings programs are funded by solid waste utility fees. In 2005, the basic garbage service fee was $28 per property plus $32 for each can; the basic recycling fee was $10 per collection point plus $9 per dwelling. All buildings are charged a flat fee of $38 for yard waste. Alberta has a decent PAYT program. St. Albert offers a combined bag/tag and variable container system as part of its user-pay program. This was the first community in Canada to implement a variable container system. Introduced in 1996, St. Albert had a 38% reduction in waste going to landfill and a 50% increase in recycling in the year 2000.

Electronic Products Recycling Associations (EPRA) are present in British Columbia, however, not in Alberta. All residents and businesses in British Columbia can recycle old electronics free of charge through an EPRA British Columbia drop-off centre (BCepra, 2013).

Extended Producer Responsibility (EPR) is one of the most important systems to promote recycling. EPR is a policy approach in which a producer's responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle. It is present in both Alberta and British Columbia. British Columbia is the only province that has mandated a full producer responsibility program for packaging and printed paper (RCBC, 2015). Alberta is planning a new regulation that will include provisions to enable EPR. To understand the EPR program and to compare this program in Alberta and British Columbia, Table 4.3 highlights the available stewardship programs.

An interesting finding is observed in the Table 4.4, it is seen that, in Alberta more deposits are required than British Columbia for each beverage bottle. Although Alberta requires more deposit, the performance of recycling is not good in Alberta. Therefore, a conclusion can be made that it is not a driving factor to have higher bottle deposit whereas British Columbia is doing excellent job without taking more deposits from beverage containers.

Table 4.2: Waste Regulations and Recycling Policies in Alberta and British Columbia

	Alberta	British Columbia
Extended Producer Responsibility (EPR) Programs	Not Available	Available
Curbside Recycling Programs	Available	Available
Electronic Products Recycling Association (EPRA)	Available	Available
Pay as you Throw (PAYT)	Available	Available
Recycling Depots	Available	Available
Organic Depots	Available	Available
Collection Bans	Available	Available

Table 4.3: EPR program in Alberta and British Columbia (SWMP 2007)

		Alberta	British Columbia
Container Deposit	Beer	√	√
	Soft Drinks	√	√
	Liquor	√	√
EPR/ Product Stewardship	Packaging		
	Printed Papers		
	Lubricating Oil	√	√
	Paint		√
	Other HHW		FP*
	Pharmaceuticals		√
	Electronics	√	√
	Sharps		
	Tires	√	√
National Volunteer	Ozone Depleting Substances	√	√
	Rechargeable Batteries	√	√

Note: * FP stands for Flammable and Pesticides

Table 4.4: Recyclable Beverage Container in Alberta

Province	Non-Alcohol: Up to and including 1L	Non-Alcohol: Over 1L	Alcohol: Up to and including 1L	Alcohol: Over 1 L
AB	10 ¢	25 ¢	10 ¢	25 ¢

4.3.2 Waste Diversion and Education

According to some studies education is one of the factors behind the recycling practices (Troschinetz and Mihelcis, 2009). In case of Alberta and British Columbia, educational attainment of the people of Alberta and British Columbia is positively related to the total waste diversion in these provinces (Figure 4.9). Therefore, it can be said that, with the increase of educational attainment, the amounts of wastes diversion also increases in Alberta and British Columbia. Education increases knowledge about social responsibility and awareness about the necessity of the waste diversion. Here educational attainment means the rate of people among 25 to 64 years old with education level of upper secondary, post-secondary and tertiary education (EI Canada, 2012). According to a study conducted in Alberta and British Columbia, level of education had an impact on the participation of recycling (HES, 2007). The study showed that, the percentage of people with 0-8 years of schooling or with some secondary education participated in recycling was 92% and 96% in recycling in Alberta and British Columbia respectively. On the other hand, people with a university degree participated in more percentage in recycling, about 99% in both the provinces.

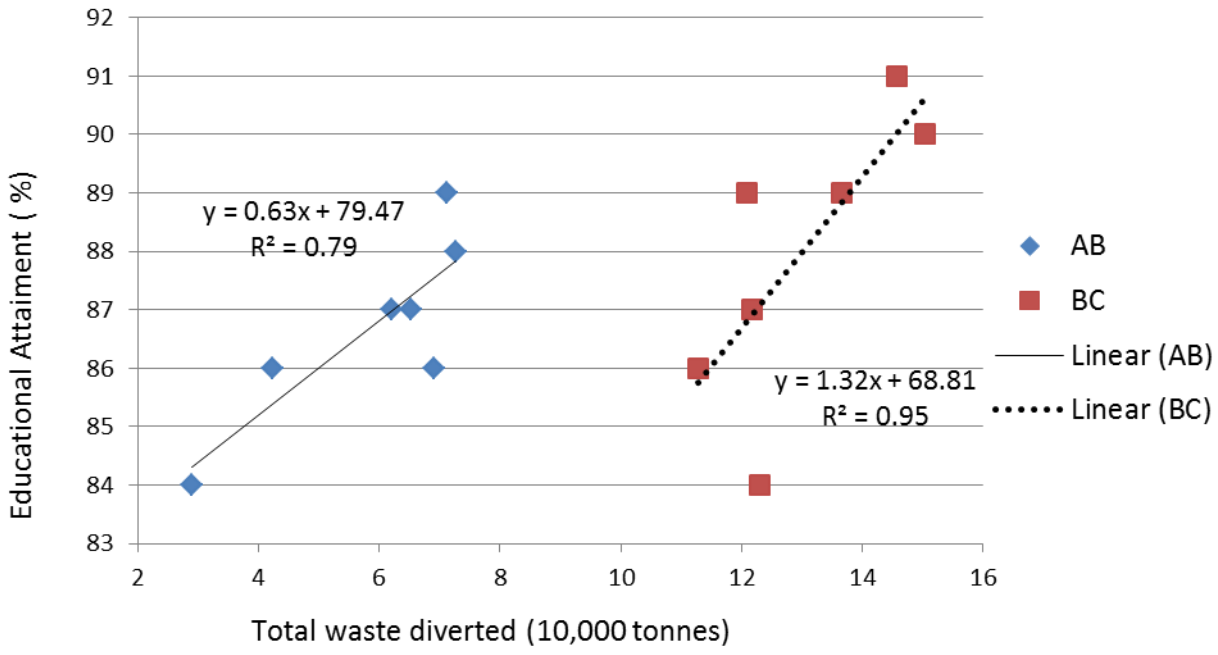

Figure 4.9: Relationship between educational attainment and the total waste diverted in Alberta and British Columbia

4.3.3 Waste Diversion and Expenditure in Waste Management

Alberta and British Columbia spent almost same amount of money per capita to operate solid waste management system in the business sector during the study period, except in the year 2008 and 2010, as shown in Figure 4.10a. In the year 2008 and 2010, AB spent roughly 53% more in the business sector. In spite of spending more money in 2008 and 2010, the waste diversion rate of Alberta on those years was almost same as the previous years and less than British Columbia. Thus, it can be said that, expenditure in the business sector is not the driving force to increase the waste diversion rate. In the business sector, the operating revenues per capita of waste management in Alberta and British Columbia were $284.84 and $178.04 respectively in 2010 (WMIS, 2013). In Alberta 255 businesses and in British Columbia 282 businesses were involved in waste management industry.

On the other hand, if focus is given to the current expenditure in Government sector as shown in the Figure 4b, it is observed that, from 1996 to 2008, British Columbia spent more money per capita than Alberta and Alberta spent more money per capita in the government sector in 2010. In spite of spending more money in 2010, Alberta's diversion rate is lower than British Columbia's. It is noted that, the expenditure in the Government sector was quite less than the expenditure in the business sector for both the provinces. So a conclusion can be made that, expenditure in the government and business sector does not play a significant role behind the difference of performances in waste diversion in these provinces. The reason might be something else, like policies, rules and regulations, awareness, dwelling type etc. In the Government sector, the operating

revenues per capita in the waste management were respectively $117.42 and $96.80 in Alberta and British Columbia in 2010 (WMIS, 2013).

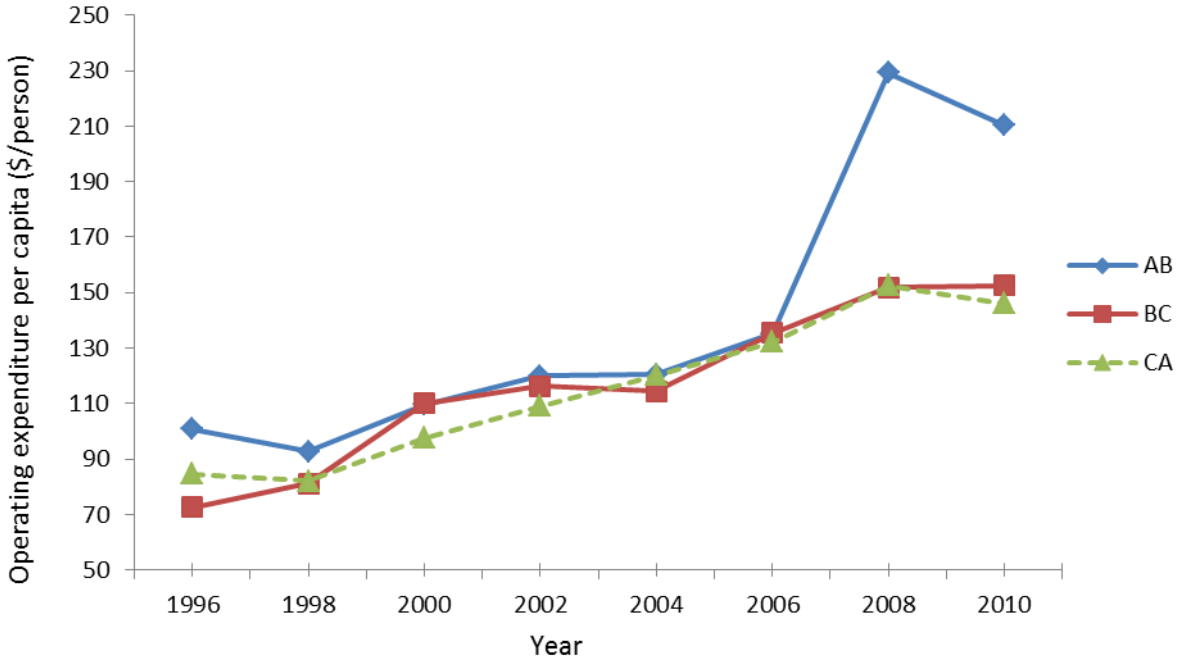

Figure 4.10a: Operating expenditure per capita in business sector in Alberta and British Columbia

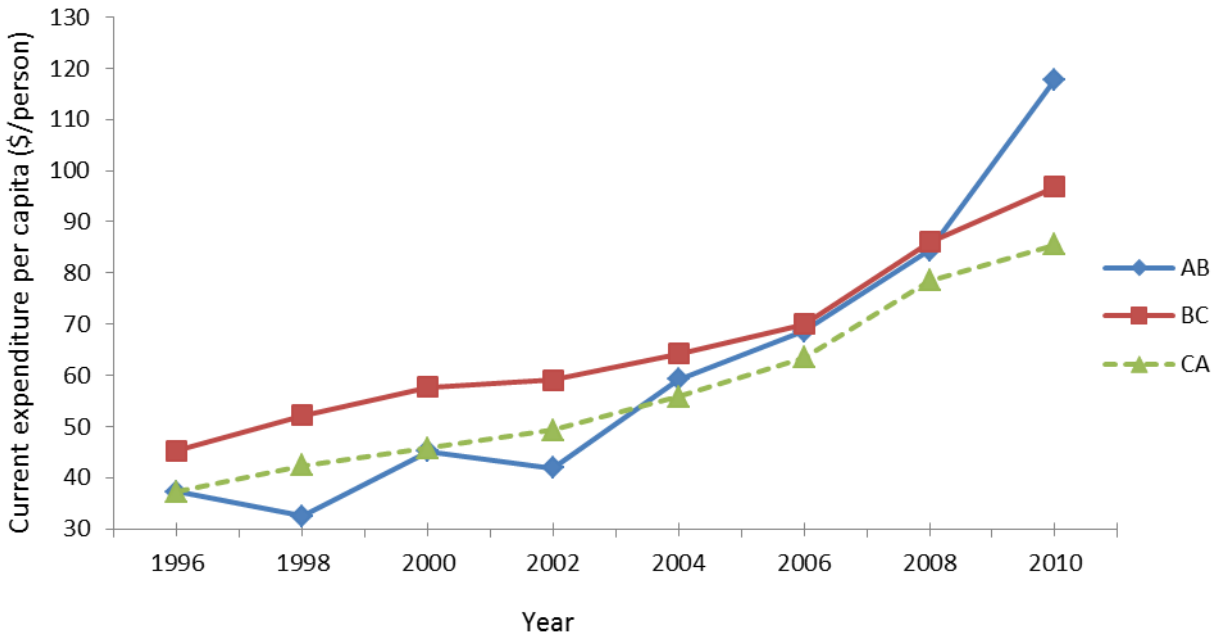

Figure 4.10b: Current expenditure per capita in Government sector in Alberta and British Columbia

4.3.4 Participation in Waste Diversion

Waste diversion is any physical transformation of materials in preparation for recycling or reuse. Such activities include sorting, cleaning and volume reduction as well as composting. Figure 4.11 shows six main composition of diverted waste in Alberta and British Columbia from 1996 to 2010. Here all waste diverted values were reported by weight. It is quite interesting to point out that Albert recycled more organic wastes than British Columbia. The reason might be that Alberta had a landfill ban of organics; however, British Columbia did not have it during the study period. Alberta has an estimated 130 composting facilities of various sizes, everything from high tech to low tech. In British Columbia, there was no public composting facility licensed under CRD bylaw. It is observed that, in diversion of paper, metal, plastic and construction, renovation and demolition wastes, British Columbia was way ahead of Alberta. The average diversion rate of paper in British Columbia is 107.42 kg/capita while in Alberta it is only 60.35 kg/capita. It is might be due to the fact that, British Columbia is the only province in Canada who has mandated full producer responsibility for packaging and printed paper.

The level of recycling, however, varies quite widely from province to province. While some of this variability can be explained by differences in levels of household income, education and age of residents. One of the key factors influencing recycling rates in Canada is whether people have access to recycling programs. When focus is given to the participating in recycling, one thing that comes to the mind is the access to the recycling programs and use of these programs. In the Figure 4.12, it is seen that, in British Columbia, for each category of recyclable materials, such as paper, plastic, glass and

metal, the access to the recycling programs were more than those in Alberta. Access to recycling means that houses or apartments with the facility of recycling for each recyclable material. These data were collected from a survey by Statistics Canada (HES, 2007) and the participation rate in this survey ranged from 68.9% to 78.7%. As in British Columbia, people had more access to recycling, subsequently they could utilize them and their recycling rates were higher than Alberta.

Table 4.5 shows the percentages of people with the access of recycling plastic packaging in Alberta and British Columbia. From the Table it is observed that, for each type of plastic packaging such as bottles, jugs and jars, non-bottle rigid container and other specific plastic materials, people of British Columbia has more access than Alberta.

British Columbia not only has higher access to recycling, however, also utilizes those facilities as it is seen in the Figure 4.13, for each recyclable material, people in British Columbia use the recycling programs more than people in Alberta.

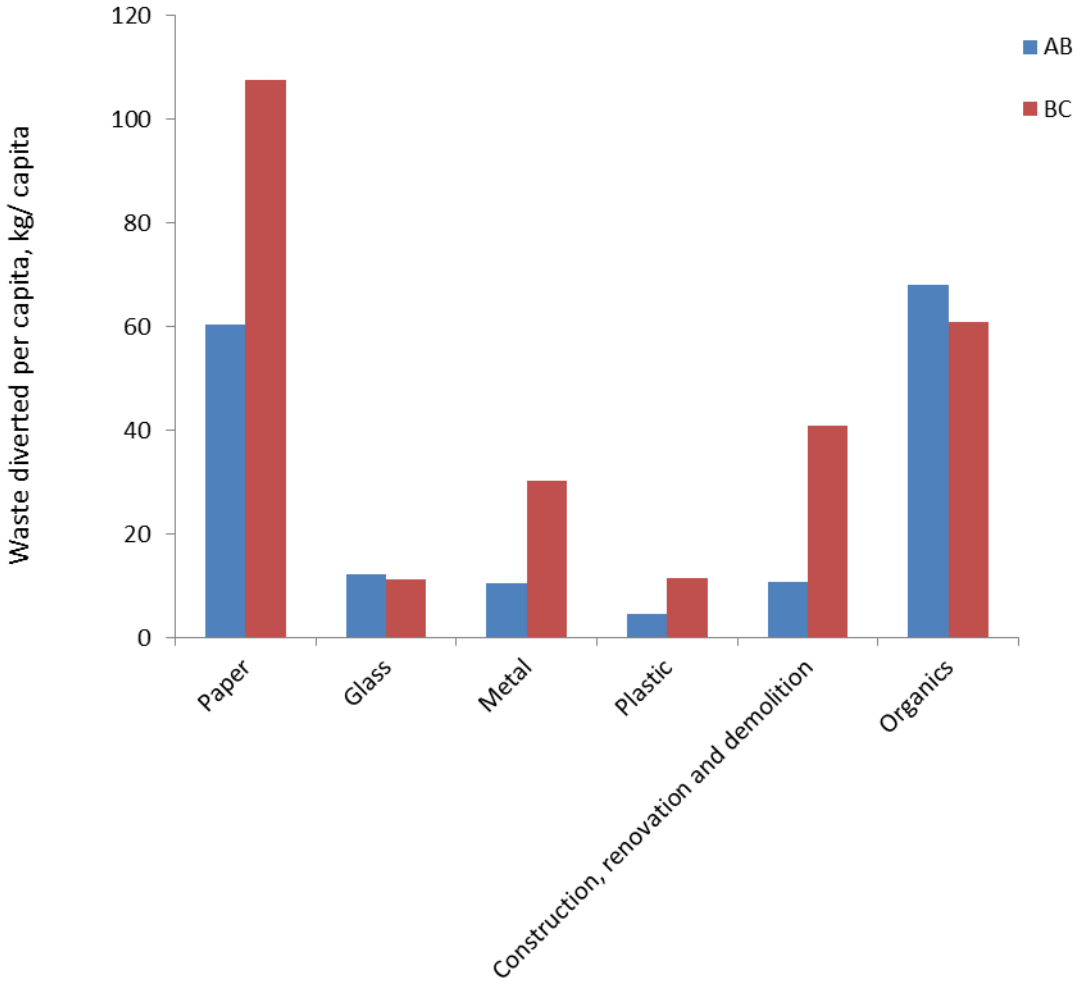

Figure 4.11: Average composition of diverted waste in Alberta and British Columbia from 1996 to 2010

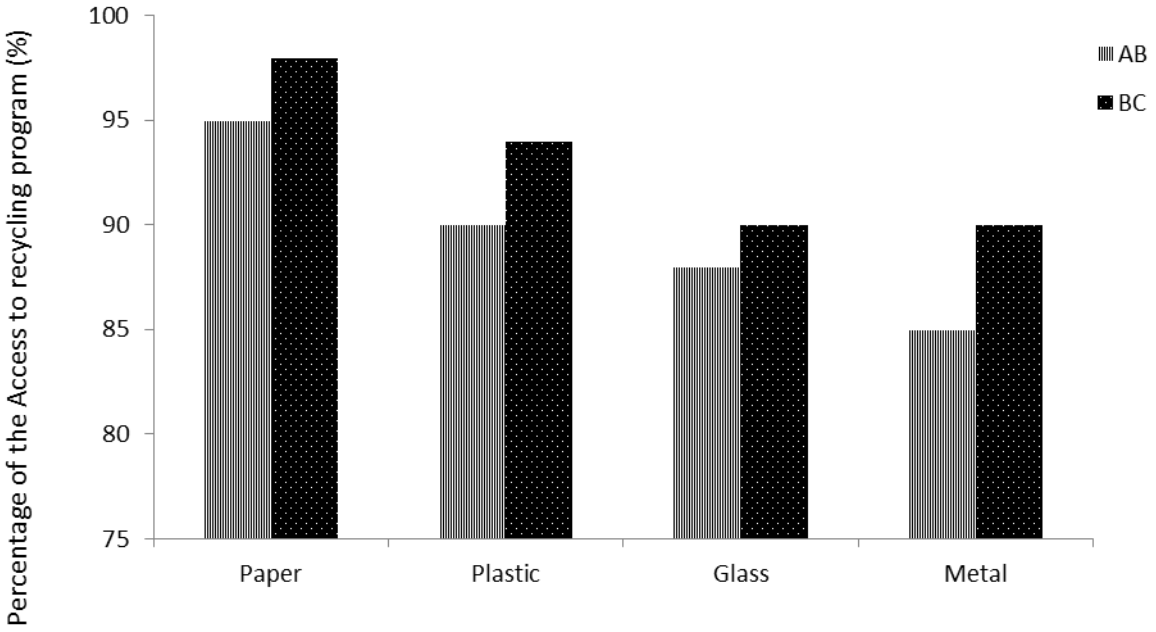

Figure 4.12: Access to the recycling program in Alberta and British Columbia, 2007

Table 4.5: Percentages of people with access to recycling plastic packaging in Alberta and British Columbia (2013)

Recyclable Item	AB	BC
Bottles, Jugs and Jars (%)	79	84
Non Bottle Rigid Container (%)	69	73
Other Specific Plastic Materials (%)	21	31

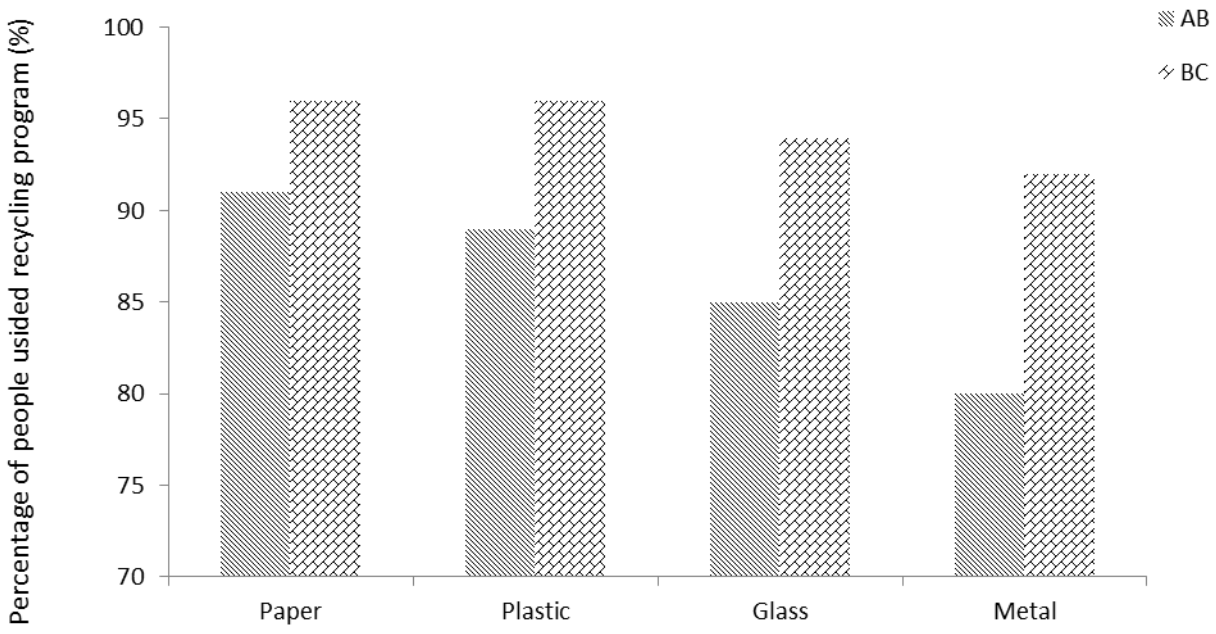

Figure 4.13: People with access to recycling used the program in Alberta and British Columbia, 2007

4.4 Linear Waste Diversion Model

Figure 4.14 shows the linear model of waste diversion rates of Alberta and British Columbia. From the figure, it is observed that, the waste diversion rate of British Columbia is increasing more rapidly than Alberta. In this figure the data from 1996 is omitted as there was an inconsistency of data in British Columbia on that year. From the Figure 4.19, it can be estimated that, if all factors remain same, at the end of 2020, the waste diversion rate of Alberta and British Columbia would be about 16% and 42% respectively. However, if all factors governing the waste diversion rates in British Columbia and Alberta become same and the policies and regulations of waste diversion becomes same both in Alberta and British Columbia, then at the end of the year 2020; the waste diversion rate in Alberta would be 23%. It was calculated by drawing a parallel line of diversion rate of British Columbia from the 2010 data of Alberta till 2020. After that the data of the point in 2020 was taken.

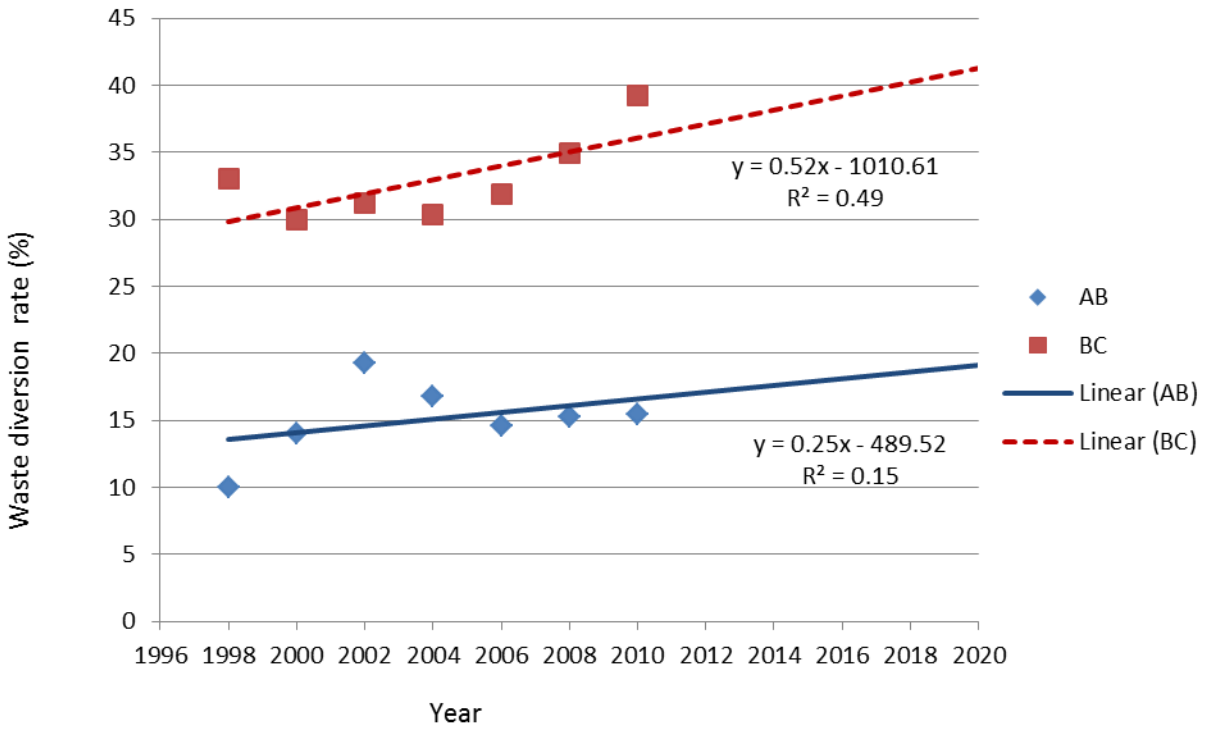

Figure 4.14: Linear model of waste diversion rate in Alberta and British Columbia

5. CONCLUSION

In this study, the generation characteristics and diversion practices of solid waste management systems in Alberta and British Columbia are examined. The major findings of this study are:

- During the study period, non-residential waste generation rates was considerably higher than the residential wastes generation rates in both Alberta and British Columbia. In Alberta the average residential waste generation and non-residential waste rates were 31% and 69%, respectively. In British Columbia, the average residential waste generation and non-residential waste generation rates were 40% and 60%, respectively. The average per capita residential waste generation rates in Alberta and British Columbia were about 0.97 kg/capita•day and 0.91 kg/capita•day, respectively.
- Generation of residential waste has shown a positive relation with the household income. From 1996 to 2010, the generation of residential waste in Alberta has increased 54.17% and family income has increased 63.64%. In British Columbia, the generation of residential waste has increased 49.12% and the family income has increased 19.63%.
- Gross Domestic Product and non-residential waste generation are positively correlated in both Alberta and British Columbia.

- British Columbia was more effective in its waste diversion programs. During the study period, the average waste diversion rate was 14.5% in Alberta and 30.6% in British Columbia.
- A positive relation was found between the total waste diverted and the educational attainment of the residents in both provinces.
- Almost all the policy's related to waste diversion is better in British Columbia. Alberta has a decent diversion policy in residential wastes. However, in diversion of non-residential waste, Alberta is way behind British Columbia. It is found that the curbside recycling program in British Columbia was very effective for waste diversion, especially for residential wastes. Similar programs were not available in all locations in Alberta. The Extended Producer Responsibility (EPR) program in British Columbia was found very effective for waste recycling, while similar program was not implemented in Alberta.
- Expenditure in business and in the government sector does not play a significant role in waste diversion rate in these two provinces.
- Results suggested that residents in British Columbia on average had more accesses to recycling than residents in Alberta. Different types of recyclables such as paper, plastic, glass and metal were widely accepted in British Columbia.
- Simple linear models on total waste generation, residential and non-residential waste per capita and the diversion rate in both provinces were proposed.

6. RECOMMENDED FUTURE WORKS

- During the study period, Canada had a recession from 2008 to 2010. In this study Canada's economic condition was not explicitly considered. In future study, Alberta and British Columbia's economic conditions can be considered and investigation can be done about its impact on solid waste management industry.

- In this research, only linear models were used for the analysis and the prediction. In some cases, the R^2 values are low ($R^2 = 0.04$ in Figure 4.7), suggesting a non-linear trends. Non-linear models are suggested in these cases.

- Despite of the many similarities, the land use pattern and the weather conditions of Alberta and British Columbia are quite different. The agricultural and energy sectors in Alberta are much more influential than British Columbia. The average precipitation rate in British Columbia is considerably higher than Alberta. These can have measureable impact on the solid waste management and diversion practices of these provinces. The possible impact(s) of climate and land usage on waste diversion can be considered.

- The actual design and implementation of various recycling initiatives and programs in these provinces can be examined.

- More focus should be provided to the generation and management of the non-residential waste in these provinces, as non-residential waste is the major waste component in both provinces.

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