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USING THE DIVERSION SIZE INDICATOR TO EVALUATE CANADIAN WASTE MANAGEMENT SYSTEMS

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Abstract: Within the Canadian federation, provinces and territories are often thought of as labs for incubating new ideas and policies. With regards to waste management, this appears to be the case as some provinces and territories have vastly different systems and outcomes when compared to others. Further understanding these waste system differences and similarities and outcomes can help to spread best practices within Canada and abroad. Therefore, this study introduced a novel waste diversion indicator called the Diversion Size Indicator (DSI) and applied it to analyze waste systems across Canada. As a measure of efficiency in a waste system, results from the analysis shows that Nova Scotia has the highest DSI of all jurisdictions studied at 16,316%, a rise of 17% from 1998 to 2014. All other jurisdictions had a lower DSI during the same period, with percentage decreases ranging from 44% to 73%. Using the coefficient of variation, it was found the greatest variability in the DSI occurred in the prairie provinces of Manitoba, Saskatchewan, and Alberta, who all also had a greater than 60% decrease in DSI. Median values of the DSI from 1998-2014 showed Prince Edward Island having a high DSI along with Nova Scotia and British Columbia, indicating efficient waste management systems in these provinces. Utilizing this indicator can help improve the efficiency of waste systems, reduce the costs to citizens, and provide the impetus for waste firms to innovate and find ways to further reduce costs.

1 INTRODUCTION

According to Cervantes et al. (2018), 377 different indicators have been used to evaluate solid waste management systems. Many of these indicators suffer from a lack of standardization and comparability between jurisdictions (Cervantes et al. 2018). One indicator that is widely used and jurisdictionally comparable is the waste diversion rate; however, it does not fully encompass the efficiency of a solid waste system (Pan et al. 2018). This necessitates the development of new indicators that are able to be compared and used across jurisdictions to fully understand the efficiency of solid waste management systems.

Provincial waste management system comparisons have been completed in the past by Wang et al. (2016), Bruce et al. (2016), Richter et al. (2017), and Richter et al. (2018); provincial jurisdiction abbreviations can be found in Table 1. Wang et al. (2016) analysed data from SK and MB and found that MB generated 17.5% more residential waste than SK, all the while producing 15% less non-residential waste than SK. The study also found that curbside recycling programs and pay-as-you-throw collection systems may be important for increasing diversion in SK (Wang et al 2016). Bruce et al. (2016) studied waste management in AB and BC, finding annual family income positively related to residential waste generation, while BC's waste diversion rate was more than double that of AB's. Richter et al. (2017) reviewed disposal and diversion trends in NS, QC, ON, and CA with respect to economic and waste business characteristics. The study

found that NS's waste diversion increased by 35% from 1996 to 2010 and NS also has the most number of waste businesses per capita (Richter et al. 2017). Richter et al. (2018) conducted multiple linear regression on NS, QC, ON, and CA data finding that NS spent less on collection and transportation than other jurisdictions and that diversion rates increased with increased budget allocation for organics and recycling facilities after a lag time of 5-8 years.

Table 1: Canadian Jurisdictional Abbreviations

Abbreviation	Jurisdiction	Abbreviation	Jurisdiction
CA	Canada	ON	Ontario
NL	Newfoundland and Labrador	MB	Manitoba
PE	Prince Edward Island	SK	Saskatchewan
NS	Nova Scotia	AB	Alberta
NB	New Brunswick	BC	British Columbia
QC	Quebec	YT, NT, NU	Yukon, Northwest Territories, and Nunavut

Most recently, Pan et al. (2018) continued the cross provincial research in this area by using indicators to compare four western Canadian provinces: MB, SK, AB, and BC. These include the Waste Management Output Index (Indicator) (WMOI), the Diversion-GDP ratio (DGDP), and the Diversion-Expenditure ratio (DEXP) (Pan et al. 2018). Through the DGDP ratio, Pan et al. (2018) showed how higher economic outputs from waste management services did not have an equally higher increase to diversion rates. Also, Pan et al. (2018) showed a slight decline in DEXP from 1998 to 2014, suggesting declining waste system cost effectiveness in the four provinces studied.

The objectives of this study are to (i) introduce a new waste diversion indicator to better measure efficiency in waste management systems and (ii) use the new indicator to analyze the federation of Canada, identifying efficient and inefficient waste management systems.

2 METHODOLOGY

2.1 Data Acquisition

Data for this study was gathered from Statistics Canada, specifically the Waste Management Industry Survey: Business and Government Sectors reports, as well as Gross Domestic Product (GDP), materials diverted, and disposal of waste tables (Statistics Canada 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2019a, 2019b, 2019c). The variables gathered from these sources include the waste materials diverted, waste materials generated, GDP of North American Industrial Classification System (NAICS) sector 562, and GDP of all NAICS industries in Canada (Statistics Canada 2016). From these variables, three derived variables were calculated: diversion rate (DR), Waste Management Output Indicator (WMOI) (Pan et al. 2018), and Diversion Size Indicator (DSI).

2.2 Derived Variables Used

The DR is shown in Equation [1]. It consists of a ratio of the total materials diverted through the use of recycling or organics processing facilities divided by the total materials generated (Statistics Canada 2010). The materials generated includes materials from non-hazardous sources as well as the total materials diverted through a recycling or organics processing facility (Statistics Canada 2010). DR is often cited as a goal for waste management organizations which drives decisions and policies within the organization (Pan et al. 2018).

$$[1]\ DR = \frac{\text{Materials Diverted}}{\text{Materials Generated}}$$

The WMOI, as first introduced by Pan et al. (2018), utilizes the NAICS to show the proportional size of a waste management system as compared to all other industries in the NAICS. Its formula is shown in Equation [2]. WMOI shows the relative economic output of a waste management system in a given jurisdiction. The variables GDP NAICS Sector 562 and the GDP NAICS All Sectors used in Equation [2] are bolded in Figure 1.

$$[2]\ WMOI = \frac{\text{GDP NAICS Sector 562}}{\text{GDP NAICS All Sectors}}$$

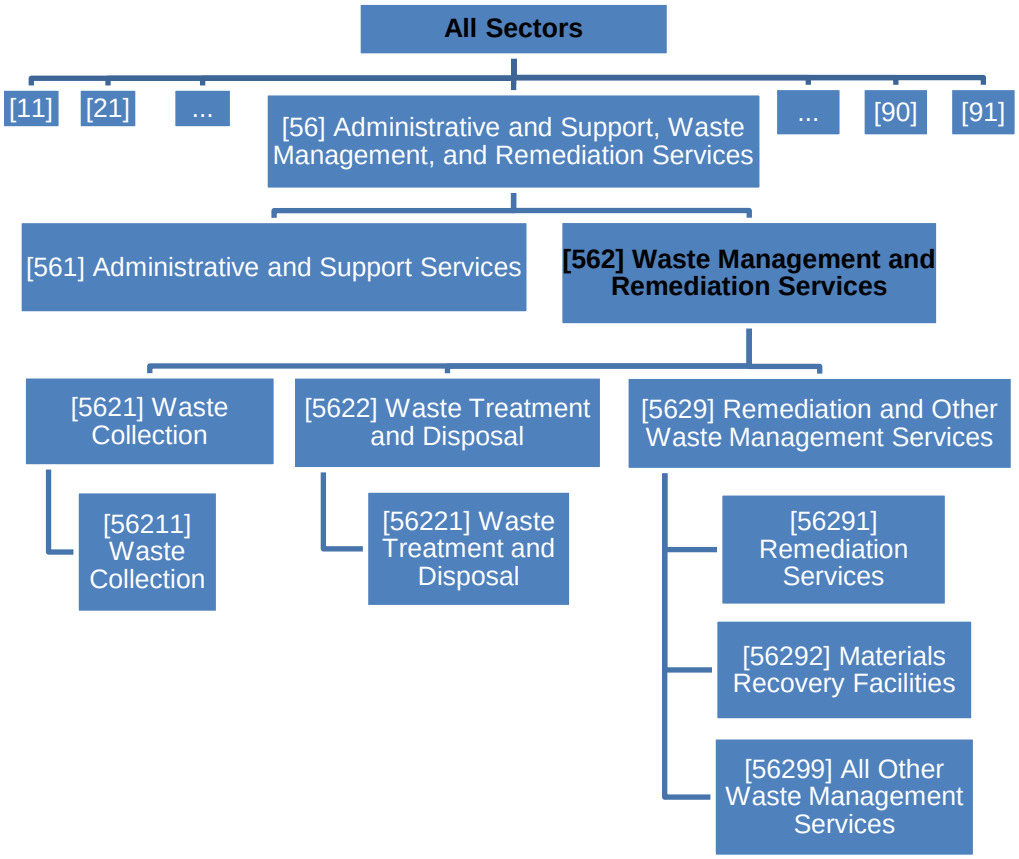

Figure 1: North American Industrial Classification System (NAICS), Partial (Statistics Canada 2016)

The All Sectors variable is shown at the top of Figure 1 and is the value of all goods and services produced in all NAICS categories from 11-91 within a year, in a given jurisdiction (Statistics Canada 2016). Sector 56 is one of the 11-91 categories and includes both Administrative and Support Services as well as the Waste Management and Remediation Services. This is then split apart at the lower level, into Sector 561 and 562. Inside Sector 562 Waste Management and Remediation Services, there includes Waste Management,

Waste Treatment and Disposal, as well as Remediation and Waste Management Services. Unfortunately, since remediation is included in this category, it includes a wider range of waste services outside of non-hazardous waste management including the cleanup of contaminated buildings, soil, groundwater, and mine sites as well as septic pumping and other waste services (Statistics Canada 2016). This means that the data presented includes all these sectors of remediation and this larger definition of waste management sector must be considered when discussing the WMOI.

2.3 Diversion Size Indicator

The Diversion Size Indicator (DSI) is a new indicator designed to measure a jurisdiction's diversion rate with respect to the relative size of its waste management industry. Equation 3 details the actual calculations to create the indicator.

$$[3]\ DSI = \frac{DR}{WMOI}$$

As seen in Figure 2, the DSI can be seen as an Input-Output indicator. Therefore, to ensure higher efficiency in the waste management industry, the ability to reduce the inputs and raise the outputs or quality is desirable. This means that a higher DR and a lower WMOI can be a goal of the waste management industry. The DSI measures this goal and a higher DSI can be thought of and used to identify a more efficient system. The DR used in this study is in terms of percentage and the WMOI is used as a decimal, therefore leaving the DSI in the units of a percentage value.

3 RESULTS AND DISCUSSION

3.1 WMOI Context

There are several ways a WMOI can be interpreted. Since it is a relative size measurement of the waste management industry NAICS Sector 562, it can be thought of in two ways. The first view is that the waste management industry is a necessary evil, and not an end in industrial production itself. The rationale is that in a hypothetical zero waste world, there would be no demand for waste management as it is not needed and the WMOI would be 0. Since this is not possible in the foreseeable future, a smaller GDP in Sector 562 is desirable. The second view is that since waste management in Canada is so far away from a zero waste world, a larger waste management sector means a better more technologically sophisticated waste system. Therefore, a higher WMOI is actually a good thing. Since it also increases the GDP of an area, as waste management services are counted as a good or service, it can also help to increase the economic output of a jurisdiction. That being said, in the following analysis, WMOI will be understood according to the first view as an input into the production system of waste management and something to be minimized. Further, the diversion rate will be understood as a measure of the output quality of a waste management system. This can be seen in Figure 2.

Figure 2: Input-Output Flowchart for the Waste Management Industry

3.2 DSI Values and Percentage Difference

Figure 3 shows the results from the tabulated DSI for Canadian jurisdictions from 1998 to 2014. It also includes a Canadian average on the left side for reference. As can be seen, some jurisdictions (including NL, PE, and YT, NT, NU) do not contain all data points for every second year as some data has been

suppressed for confidentiality under the Statistics Act (Statistics Canada 2010). However, a full range of data is available for 8 of the 11 jurisdictions under study.

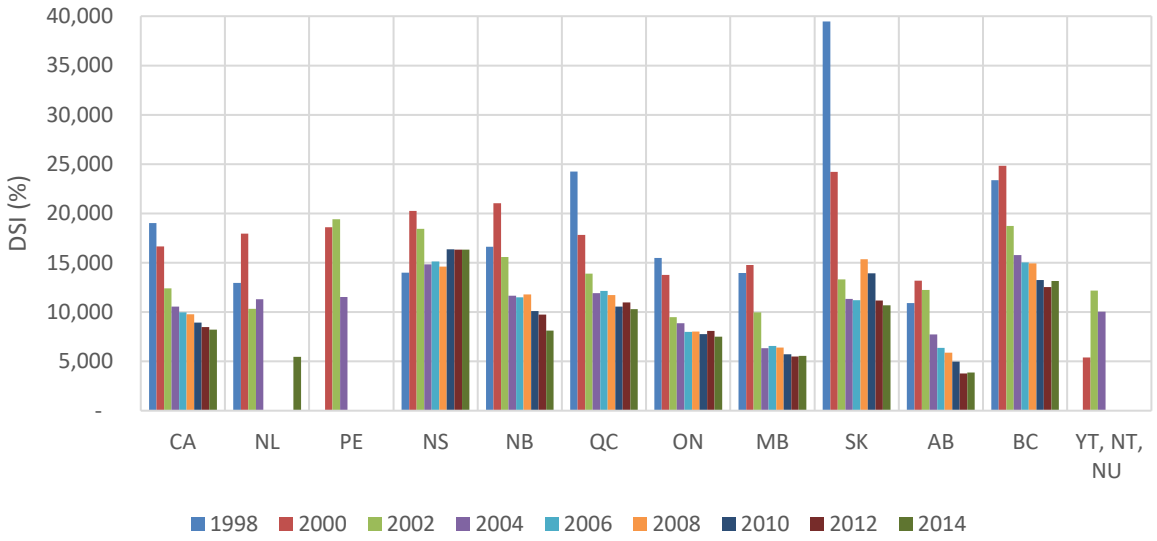

Figure 3: Diversion Size Indicator by Jurisdiction and Year (Statistics Canada 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2019a, 2019b, 2019c)

In reviewing the data, all jurisdictions in 2014 had a lower DSI than they did in 1998, except NS. NS started out at DSI=13,986% in 1998 and then rose 17% to DSI=16,316% in 2014. This contrasts sharply with every other jurisdiction whose DSI decreased between 44% and 73% during the same period from 1998 to 2014. In 2014 DSI, 4 of the 9 provinces with data were above the Canadian average. These four provinces were NS, QC, SK, and BC. The five lowest provinces included AB, NL, MB, ON, and NB. The lowest of all was AB, scoring only 3,868%, a full 123% difference from the highest province (NS) in 2014, as shown in Figure 4.

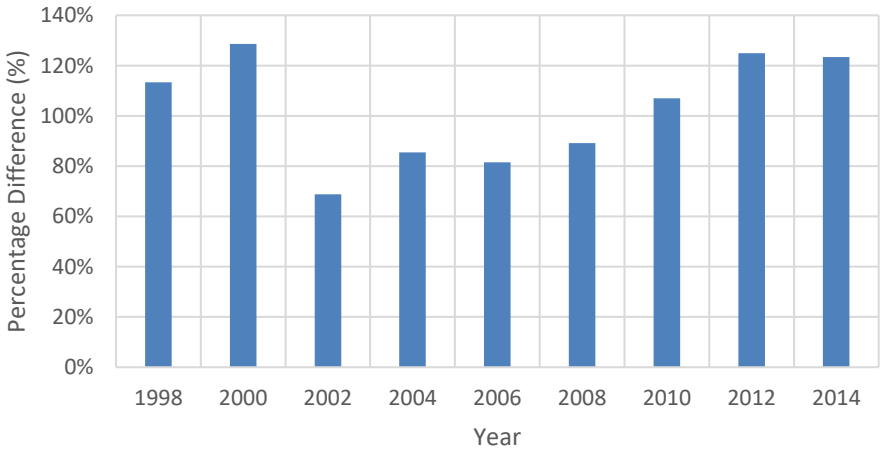

Figure 4: Diversion Size Indicator Percentage Difference between Highest and Lowest Province by Year (Statistics Canada 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2019a, 2019b, 2019c)

Figure 4 shows that provinces had a great deal of divergence in DSI's in 1998; differing by 113%, climbing to 129% in 2000, but then falling drastically in 2002 to only a 69% difference. Finally, by 2014 it had risen to 123% difference. This suggests a great deal of difference within the federation of Canada's waste management systems. This difference between jurisdictions highlights the benefit of such analysis to further understand both efficient and inefficient jurisdictions to help yield more cost effective waste management systems.

3.3 DSI Ranking

Ranking can also be used to analyze the DSI from 1998 to 2014. Ranking was completed on 9 of the 13 provinces and territories with data in both 1998 and 2014. Figure 5 shows these rankings and the change in ranking from 1998 to 2014. Note that a negative change in ranking is a good thing as this means their ranking has gotten closer to the number 1 rank, and vice versa. Looking at all the provinces, only two moved up in ranking (NS and BC), four moved down in ranking (NB, QC, ON, and SK), and three kept the same ranking (NL, MB, and AB). By this measure, two provinces have gotten better than their peers from 1998 compared to 2014, including both NS (which had an absolute increase in DSI) and BC (which had a 44% decrease in absolute DSI over the period). This 44% decrease in BC was actually the lowest percentage decrease of all the other provinces with data, highlighting the level to which DSI has fallen from 1998 to 2014. The four provinces that had a decrease in ranking all fell in absolute DSI and this percentage decrease ranged from 51% to 73%. The three provinces that had no change in ranking were all at the bottom of the rankings, ranking 7th, 8th, and 9th, leaving places 1st to 6th as the positions that changed. This shows that at the lowest DSI rankings, there was not much change or improvement over the 16-year study period. This ranking analysis helps to show three distinct groupings of those increasing in efficiency, those staying the same, and those getting less efficient in relative comparison to their peers. This can useful for future analysis as to what caused these systems have changed in relative positions over time.

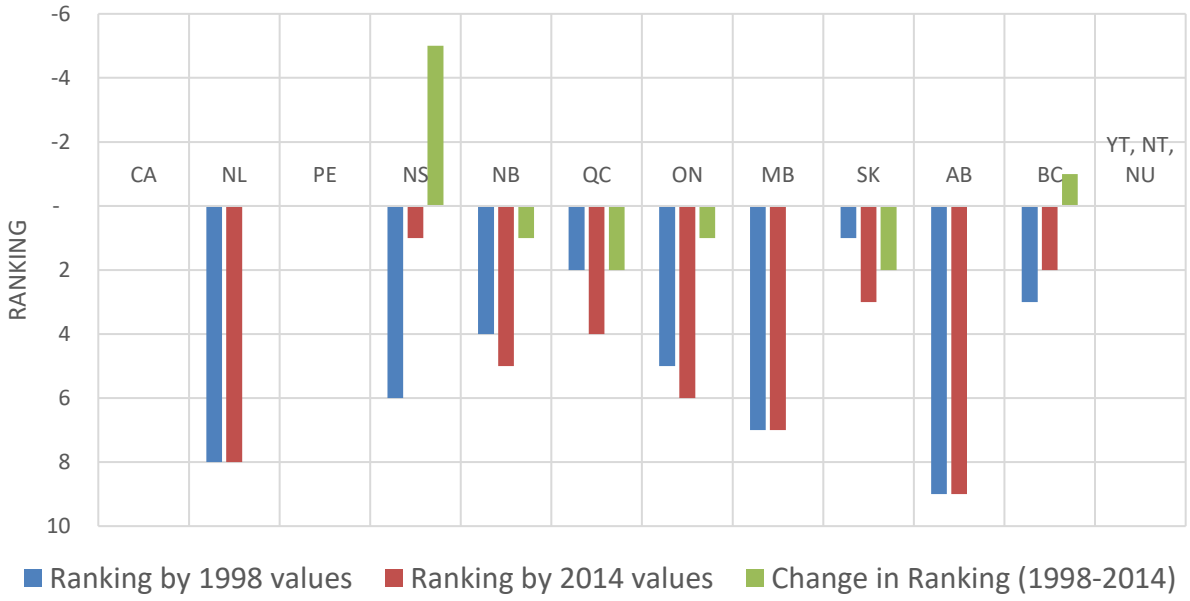

Figure 5: Diversion Size Ranking by Province (Statistics Canada 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2019a, 2019b, 2019c)

3.4 DSI Coefficient of Variation

Figure 6 shows the provinces DSI standard deviations divided by their mean values, or the coefficient of variation. Given the highest coefficient of variation was 57%, and three groupings were sought after, a rounded up number of 60% was used and then divided to create three groupings. The groupings are as

follows; low variation over the period 1-20%, moderate variation over the period 21-40%, and a high variation over the period 41-60%. Using these groupings, one can see where large changes have taken place over the period. The low variation group only contains NS, the moderate variation group contains 7 jurisdictions (NL, PE, NB, QC, ON, and BC), and the high variation group contains 3 provinces (MB, SK, and AB). This high variation group, consisting of all prairie provinces, has seen DSI decreases of over 60% from 1998-2014. This large decrease and large variation in DSI shows inefficiency becoming a larger problem in these waste systems. It also highlights NS as a very consistent and mature solid waste management system, providing for high diversion relative to its WMOI from 1998-2014.

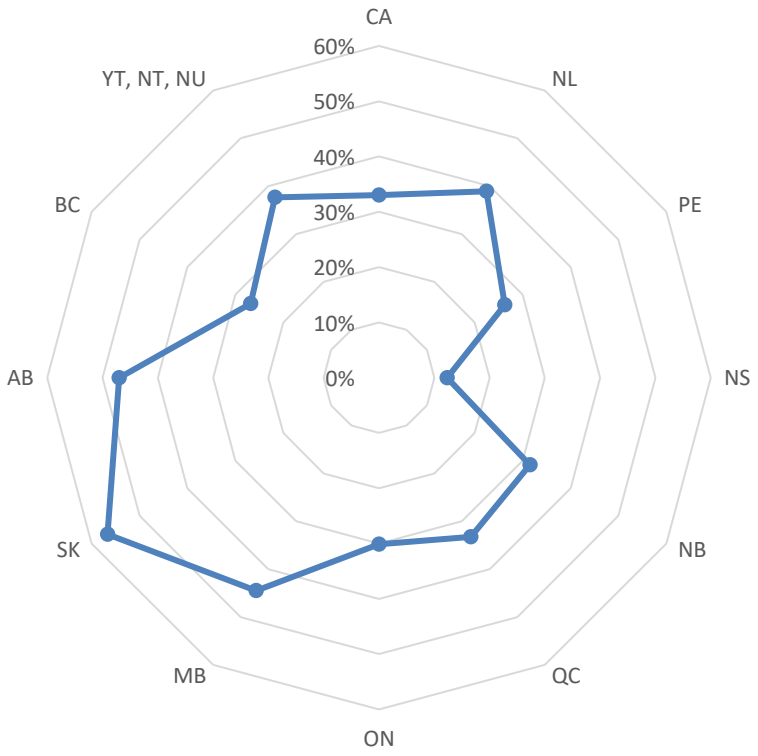

Figure 6: Diversion Size Indicator Coefficient of Variation (Statistics Canada 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2019a, 2019b, 2019c)

3.5 DSI Median Values

Using median values of all DSI data from 1998-2014 reveals the following rankings in Figure 7. Of note are the jurisdictions of NL, PE, and YT, NT, NU who all have less than full data sets for the study period, but are included here to aid in the full analysis between all jurisdictions. It can be seen that PE has achieved the highest ranking or 1st place, dethroning NS down to 2nd place, BC to 3rd, and SK to 4th. NL and YT, NT, NU are both 8th and 9th respectively. This shows that PE, while not having complete data, may also have an efficient waste management system, similar to that of NS. PE's median DSI is 18,604% (from three data points) and NS's is 16,316% (from nine data points). Unfortunately, data for PE from the same source of Statistics Canada Waste Management Industry Survey's is not available since 2004, but further investigation into the PE system can be warranted from this analysis. It should note that, given the decreasing trends of DSI in other provinces, PE's high median DSI is only gathered from 2000 to 2004 and may have since fallen or risen.

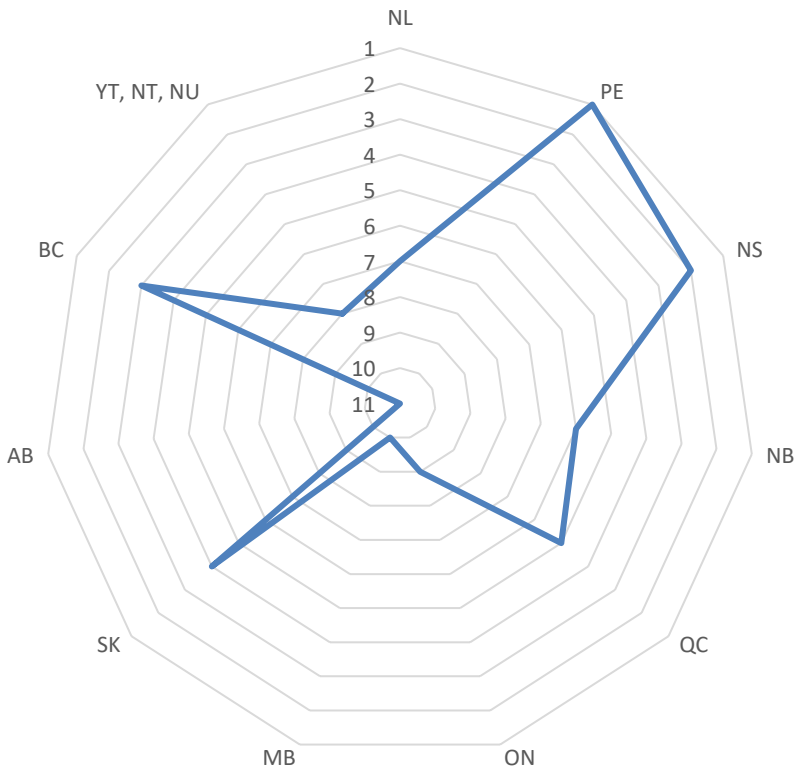

Figure 7: Diversion Size Indicator Median 1998-2014 Rankings (Statistics Canada 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2019a, 2019b, 2019c)

Given this analysis, PE, NS, and BC should be further investigated to understand their high DSI rankings. Higher DSI rankings and values in NS point to a more efficient and higher quality waste system. Findings of higher DRs in BC versus AB are also consistent with Bruce et al. (2016), higher WMOI in BC versus AB are consistent with Pan et al. (2018), and their DSI rankings reflect these values. Further analysis of the prairie provinces to analyze the changes from 1998-2014 would help to further the understanding of their large coefficient of variation. Using DSI to help analyze provinces can help to identify successfully efficient waste systems and highlight challenges in other jurisdictions with regards to waste management systems.

This is by no means a definitive efficiency measure of a waste management system. There are numerous outputs and inputs that can be analyzed to better understand what actual input and actual outputs are used and wanted in different waste systems. Further exploration of other aspects of waste system inputs and outputs will help to better explain the DSI efficiency data.

4 CONCLUSIONS

This study's objectives were to introduce a new waste diversion indicator to identify efficient and inefficient waste management systems in Canada. As per the study objectives, this study introduces a new indicator to the study of waste management system, called the Diversion Size Indicator, DSI. It uses an input-output model to show how it can be considered as a measure of efficiency of a waste industry in a specific jurisdiction. It uses the Waste Management Output Indicator as an input variable and the diversion rate as a quality output variable of the system. Using this indicator, the authors have found that all jurisdictions had lower DSI values in 2014 than they did in 1998, except for NS, which had a 17% increase in DSI, or efficiency.

Using DSI rankings, two provinces increased in rank from 1998-2014 (NS and BC), while four provinces fell in DSI ranking (NB, QC, ON, and SK). Those ranked lowest (NL, MB, and AB) also stayed ranked lowest from 1998 to 2014 suggesting little change in efficiency relative to their provincial peers.

The prairie provinces of MB, SK, and AB all had between 41-60% coefficients of variation, putting them in the high variation group over the study period; all seeing a greater than 60% decrease in DSI. However, NS had a coefficient of variation of 12%, suggesting a mature and consistent solid waste management system.

When median values were reviewed, it revealed PE as another possible standout in efficiency measured by the DSI, even surpassing NS, which had occupied the number 1 ranking when PE, NL, and YT, NT, NU were excluded due to lack of data in 1998 and 2014. This suggests further review into the efficient waste management systems of PE, NS, and BC is warranted due to their high performance throughout the DSI analysis. Further, provinces including MB, SK, and AB could be further analyzed as to why such a change occurred from 1998 to 2014. Also, the lowest ranked provinces or inefficient waste management systems of NL, MB, and AB can also be further analyzed to understand their consistently low DSI rankings over the 16-year study period.

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