Heliyon 5 (2019) e02313

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.heliyon.com

New Jersey's waste management data: retrospect and prospect

Jordan P. Howell *, Katherine Schmidt, Brooke Iacone, Giavanni Rizzo, Christina Parrilla

Dept. of Geography, Planning & Sustainability, Rowan University, Glassboro, NJ, United States

ARTICLE INFO

Original content:
https://doi.org/10.17632/7yc4c3pmtp.2

Keywords:
Environmental science
Environmental assessment
Environmental management
Environmental economics
Operations management
Research and development
Political science
Human geography
Social responsibility
Conservation
Waste
Recycling
Environmental data
Solid waste management
New Jersey

ABSTRACT

Reliable data about collection, volume, tonnage, stream composition, and disposal price have long been described as key components of successful solid waste management planning. Yet, concerns about data quality and quantity have continued to limit even the most sincere, progressive waste management schemes. This paper examines solid waste management data that has been collected in the US state of New Jersey starting in the 1960s. We present the origins of waste management data collection in New Jersey and trace some of the applications that have been made with the data over time. We compare the New Jersey dataset to waste management data that has been collected in other US states. We then describe our work collecting, cleaning, and preparing for public dissemination and use in a geospatial visualization exercise a digital version of the data spanning approximately 1993 to 2016, before presenting some illustrations of the type of modeling and analysis that researchers or the concerned public would be able to undertake now that the dataset is available. (We are publishing the 1993–2016 dataset alongside this paper). We argue that the New Jersey waste management dataset is much better than most other waste datasets in the US, but despite this fairly high quality, there remain significant gaps which inhibit the ability of planners to design and implement comprehensive waste management plans. That there are limits inherent to the New Jersey dataset suggests, we argue, a ceiling to the usefulness of waste management data as a category of environmental knowledge with possible implications for 'big' environmental data more broadly.

1. Introduction

Reliable data about collection, volume, tonnage, stream composition, and disposal price have long been considered a vitally important aspect of successful solid waste management planning (Melosi, 2000, 2005; MacBride, 2012; Offenhuber, 2017). Yet, concerns about data quality and quantity have continued to limit even the most sincere, progressive waste management schemes. Even when data quality has been excellent, there still exists the political, financial, and cultural challenges of applying data insights to actual waste management infrastructure. We argue, that this is likely the result of a mismatch between the nature of the data being collected – a function of the intended uses of the collecting entity – and the ways in which different stakeholders envision the 'waste management problem' being solved. This paper examines solid waste management data that has been collected in the US state of New Jersey since the 1960s. We present the origins of waste management data collection in New Jersey and trace some of the applications that have been made with the data over time, and we compare the New Jersey dataset to waste management data that has been collected in other US states. We then summarize our process of collecting, cleaning, and preparing for public dissemination and use a digital version of the data spanning approximately 1993–2016, before presenting some illustrations of the type of modeling and analysis that researchers or stakeholders would be able to undertake now that the dataset is available.

Our work fits into the stream of historical and social-scientific research examining waste management systems, and the data associated with them, as opposed to literatures associated with technical design and engineering. Historian Martin Melosi has written extensively about the development of waste management, sewerage, and other vital urban environmental services in the US and Great Britain (2000, 2005). While comparing different time periods and geographic settings, a consistent finding in Melosi's work has been the centrality of compiling and analyzing data about phenomena like solid waste and wastewater as a component of devising and implementing solutions to the urban-environmental problems associated with rapid industrialization and urbanization. While waste management focused initially on just a handful of primarily organic materials, Melosi shows how the technological advances of the 20th century spurred development of synthetic

* Corresponding author.
E-mail address: howellj@rowan.edu (J.P. Howell).

https://doi.org/10.1016/j.heliyon.2019.e02313
Received 10 May 2019; Received in revised form 7 June 2019; Accepted 12 August 2019

wonder materials and the rise of single-use, 'throwaway' cultures. These new materials contributed to new collection and disposal practices, like recycling, that have since become commonplace. Alongside these new practices arose demands for additional data on these materials and their processing. Samantha MacBride (2012) examines the system of materials recycling currently employed in the US, and illustrates how both recycling activists and their corporate opponents mobilized quantitative data about waste management to make their cases, frequently bolstering narratives about landfill (in)capacity with additional data relating the (dis)advantages of recycling from life-cycle assessment or economic growth perspectives as part of arguments aimed at their preferred course of action.

Our project also connects to literatures concerned with environmental data and its uses. Recently, greater public attention has been paid to broader categories of environmental data, including waste management but also water and air quality, climate and temperature data, various metrics of carbon generation/sequestration, transportation, and energy intensity (cf., Offenhuber and Ratti, 2014; Bullock, 2017; Offenhuber, 2017). Bullock, in the preface to his 2017 book *Green Grades: Can Information Save the Earth?* argues that these information-based approaches and frequently, the labeling and reporting exercises that accompany them, are aimed at simultaneously educating citizen-consumers and holding companies and policymakers accountable. Bullock argues that data-based approaches to talking about, and correcting, environmental problems represent "one of the most important developments in environmental policy and management in recent years." (2017, ix) While more information about a problem can lead to improved decision-making processes, awareness of data-gathering and reporting processes is a vitally important though frequently under-considered dimension of the push for more environmental data. Offenhuber (2017) notes that to record the observations underlying any sort of quantitative measurements about the world around us requires careful consideration of the processes and flows that coalesce to produce a particular phenomenon. Thus, understanding the act of collecting data is itself central to applying any insights of that data to environmental and infrastructural problem solving. Writing in the introduction of his 2017 book *Waste Is Information*, Offenhuber argues:

> As Ernest Hemingway declared, the things that are left out are the most important parts of a narrative…Everyone has a view of the waste system, but as with the iceberg, the viewpoints are based on partial knowledge, and often our imagination is defined by what we do not see.
>
> How would the experiences of waste systems change if the public had more knowledge about their actual processes and geographies? What would we demand from municipalities? How would we express and support our doubts? How would the relationships and the interactions among citizens, governments, and other actors change? In short, how would this knowledge affect the governance of these systems?
>
> Contemporary waste systems have been shaped by many different actors who use their own representational tools. (Offenhuber, 2017, 8–9)

In our paper, we examine the data relating to waste management in New Jersey that has been collected over the past several decades. We show evidence of Offenhuber's "iceberg" notion, and namely, that a particular view of the waste management 'problem' was held by the state, local, and private entities commissioning and carrying out data collection. In other words, New Jersey's waste data was collected for particular purposes and uses within state and local government. We point this out because in this paper, we show how even a fairly robust, ostensibly environmental dataset is not necessarily useful for infrastructure planning and environmental problem-solving (though, it was surely useful for other things within the context in which it was collected). We argue that while the New Jersey waste management dataset is much better than most other waste datasets in the US, there remain significant gaps in what the data can tell us which inhibit the ability of planners to design and implement comprehensive waste management plans. That there are limits inherent to the New Jersey dataset suggests, we argue, a ceiling to the usefulness of waste management data as a category of environmental knowledge with possible implications for the Zero Waste concept and 'big' environmental data more broadly.

2. Material and method

This paper is built on examination of more than 30 years' worth of quantitative data collected by the state of New Jersey. The data fits into two general categories: waste tonnage and type, and recycling tonnage and type. Based on reports made by waste haulers, disposal facilities, and representatives of municipal government, the Division of Solid and Hazardous Waste in the New Jersey Department of Environmental Protection (NJDEP, and its variously-named predecessors stretching back to the 1970s) has compiled data from both categories for various planning, enforcement, and administrative uses, as explained in section 3.1 below. The NJDEP has long made waste and recycling tonnage data available to the public, though in the form of combined annual reports aggregated by county, or recyclable material type with no geographic association (Division of Solid and Hazardous Waste, 2019a). This study is the first to consider the disaggregated data underlying those annual reports, which is collected as follows.

The general structure of the waste tonnage data collection program has been consistent since initial efforts to collect this information began with the advent of state- and county-level waste management planning in New Jersey in the late 1960s. Waste haulers – entities, public or private that collect waste from homes and commercial establishments – would report on a paper form the origins of the waste (i.e., the town from which it was collected) and an estimate of the type of material collected. New Jersey state laws eventually articulated six different types of waste materials in the enabling and successor waste management legislation: household & municipal waste, bulky waste, vegetative waste, dry sewage sludge, animal & food processing waste, and dry industrial waste. When the hauler passed through the scales at a disposal site in the state, it would report this information to the scale house, which would in turn transmit the reports to the NJDEP at monthly intervals along with the recorded weight. Thus, estimates of material type, volume, and municipal origin could be calculated at the level of the disposal facility or municipality.

The collection procedure was similar for reporting amounts of recyclable materials, but with an important linkage to municipal funding. In the late 1980s, the State of New Jersey enacted both a mandatory recycling program and a tax on materials disposed at landfills, with the proceeds being redirected to individual towns in order to support emerging municipal recycling programs. The amount a city or town might receive through the grant program was linked to the tonnage and type of recyclable material reported to NJDEP by a designated town recycling coordinator. For instance, the NJDEP might schedule that towns receive grants of $3.00/ton of aluminum, $2.00/ton of corrugated cardboard, and $1.00/ton of newsprint or office paper – on top of and separate from the amounts a town might recover from the actual sale of the material. The grant funds were intended to further enhance recycling programs by supporting resident outreach and education, the purchase and distribution of bins for curbside service, the salary of a dedicated recycling coordinator, or similar programs. Methods of towns' reporting to the DEP, however, varied by town and certainly changed over time, with practices ranging from recycling coordinator spot checks and modeling of curbside collection routes and businesses to rougher estimates and self-reporting by towns' small businesses, recycling haulers, or public works employees on the amounts they thought their operations collected.

In both instances, the data was maintained by staff in the Division of Solid and Hazardous Waste at the NJDEP: waste tonnage data was, until the mid-2000s, manually entered into an electronic database system by

NJDEP staff, while recycling data was initially entered manually into a database before transitioning in the mid-1990s to a fully electronic reporting and data management system. In working with NJDEP staff, we determined that only the electronic records exist at this time. The recycling tonnage data stretches back to 1995 when reporting and storage became electronic, and the waste tonnage data stretches back to 1994. It was determined that earlier waste tonnage records, which existed only on individual paper forms submitted by disposal facilities, had once been archived in the state records storage system but had likely been deaccessioned due to limited public requests to examine the forms and a determination that much of the older waste tonnage data had been previously made public, in aggregate form, in county and state planning exercises (e.g., Planners Associates Inc. 1970; Musto and The County and Municipal Government Study Commission, 1972; Division of Waste Management; NJ Department of Environmental Protection, 1985; Division of Solid Waste Management; New Jersey Department of Environmental Protection and Energy, 1993b; New Jersey Department of Environmental Protection, 2006). Thus there was little perceived necessity to retain the original physical reporting documents themselves and they appear to be no longer available for analysis.

The extant waste tonnage and recycling tonnage data was converted directly by NJDEP staff from the database format it had been stored in to Microsoft Excel, after which the authors of this paper were able to prepare the data for analysis and distribution. Details on the processes used to clean the data are explained in Section 3.2 below.

This paper is one part of a larger project about the history of waste management in New Jersey, that relies also on an extensive examination of historical and archival materials relating to waste management planning in New Jersey and in-depth interviews with current and former industry participants from state and local government as well as private industry. The archival analysis included published and unpublished documents from state and local government, advocacy groups engaged in waste management issues, private firms, as well as news media collected from libraries around New Jersey and in particular the New Jersey State Library. Library and archive holdings were searched electronically for sources containing waste management keywords (e.g., waste, garbage, recycling, landfill, incinerator, etc.) in the title or subject heading. Over 500 sources were discovered in this way, and qualitatively assessed to help construct an historical narrative about changes to New Jersey's waste management infrastructure during the ‘long’ 20th century from the late 1800s to the near-present. For similar purposes, approximately 20 different semi-structured interviews were conducted with current and former participants in different aspects of waste management in New Jersey, ranging from regulatory agencies to private landfill and recycling facility operators. These interviews were digitally recorded and professionally transcribed by a transcription service, before being qualitatively assessed along the same lines as the historical documents. These two additional sets of project data serve primarily as background for this particular paper, though specific sources are foregrounded (and cited) in instances where historical materials or interview content relate directly to the data collection program we are examining.

3. Results

3.1. An overview of the NJ waste dataset and comparable datasets

Prior to passage of the federal Solid Waste Disposal Act in 1965, there was little organized gathering of data relating to waste collection and disposal. This federal law was intended to improve the state of waste management in the US, particularly by supporting demonstrations of new collection, processing, and disposal technologies and encouraging states to take a comprehensive look at how wastes were handled within their own borders – in other words, to plan for waste management. Newly forming state-level environmental agencies like the NJDEP endeavored to understand the contours of the waste disposal problem within their jurisdictions, by undertaking comprehensive studies of the amounts and types of wastes being produced.

Prior to this point in New Jersey, county governments had occasionally studied waste management, though in an ad hoc fashion, and typically in the context of either urban and suburban development planning or in response to allegations of corruption or other malfeasance (e.g., John J. Bergin and Office of the Deputy Attorney General, 1959; Monmouth County Planning Board, 1966; Perrotta, 1969; Tocks Island Regional Advisory Council and Associates. 1969; Camden County Planning Board, 1970; Mercer County Planning Board, 1971). The State of New Jersey had also occasionally been concerned with the waste industry when allegations of corruption in the industry rose to the surface. At these moments waste management data was thrust into a central role. For example, a series of hearings before a joint State Assembly and State Senate Panel in 1969 featured insights and commentary from the mayors, attorneys, and administrators of cities like Trenton, the state capital, and Kearny, a Meadowlands town with numerous landfills, as well as executives from the New Jersey League of Municipalities, an association and advocacy group for local officials. Many of the hearing participants admitted to knowing little about the actual quantities and composition of their town's waste stream, and even less about how prices for waste collection and disposal should be set by contractors. This murkiness surrounding waste volumes service pricing meant that municipal waste contracts could change dramatically in value from year to year: in one instance reported during the hearing, an increase of more than 100% in the cost of service was reported by the mayor of North Bergen, NJ, from one year to the next (Special Legislative Commission to Investigate Certain Problems Relating to Solid Waste Disposal, 1969).

For these reasons, as well as concern over the number, location, and operations practices of many town dumps (e.g., Commission to Study Problem of Solid Waste Disposal, 1965), it was determined early in the waste management planning process that accurate data about waste generation and disposal would be a vital aspect of any successful comprehensive waste management planning effort. The *New Jersey Solid Waste Disposal Program*, arguably the first publication aimed at tackling waste management from a statewide perspective, identified several organizing principles that would shape waste management planning for decades to come, but among the first was the central role of quantitative data:

> “[waste management] must rest solidly on a base of data – data about the people of the state, its industry and commerce, and its land… analysis of…type of refuse…generation rates and their change over time…suitability and capacity of existing disposal sites…the projections and forecasts required to develop short- and long-range solid waste management plans…insure continuing program responsiveness to changing or unanticipated conditions or innovations.” (Solid Waste Disposal Program; Division of Clean Air and Water; New Jersey State Department of Health, 1968, 5)

Subsequent state, county, and local plans for waste management made quantitative assessments of waste generation a main ingredient. These plans (e.g., Planners Associates Inc. 1970; Musto and The County and Municipal Government Study Commission, 1972; Division of Waste Management; NJ Department of Environmental Protection, 1985; Division of Solid Waste Management; New Jersey Department of Environmental Protection and Energy, 1993b; New Jersey Department of Environmental Protection, 2006) frequently built models pairing historic waste generation trends with projections for population, economic growth, and industrial activity as a mechanism for forecasting demand for disposal capacity. In the 1970s and 1980s these models were oriented towards estimating sanitary landfill, transfer station, and incinerator construction needs, and starting in the 1980s many of the plans also included forecasts for both quantities of recyclable materials and estimates of market size and value for these materials (e.g., New Jersey Advisory Committee on Recycling, 1980a, b, Office of Recycling; Division of Waste Management; NJ Department of Environmental Protection, 1984, 1986).

Until the early 1990s there appeared to be a clear connection between waste management volumes and infrastructure planning, particularly surrounding the construction of new disposal facilities, and especially waste incinerators. These had emerged as a key element of the approach to handle wastes in New Jersey, as state officials at NJDEP and engineering consulting firms had developed a plan for a statewide network of incinerators with one planned for each of the 21 counties (Division of Waste Management; NJ Department of Environmental Protection, 1985; Division of Solid Waste Management; New Jersey Department of Environmental Protection and Energy, 1993a). During the gubernatorial tenure of James Florio in the early 1990s, however, a moratorium was imposed on the development of new facilities due to both stumbling state finances and public outcry over the relationship between incineration and recycling as well as the program cost. Ever since, very few disposal facilities have come online in New Jersey, even as volumes of waste material have continued to increase.

Even as the actual pieces of data being collected have remained the same, a shift in purpose surrounding the state's waste data gradually took place: as plans for handling the state's still-rising volumes of waste shifted to maximizing use of existing – and rapidly ageing – disposal facilities and exporting waste to out-of-state regional landfills, the role of waste data as an element in planning efforts seems to have been minimized. Similarly, the role of data describing quantities and types of recyclable material in the state has been confined to informing the state grant-making program. It is only recently that quantitative waste and recycling data has returned somewhat to its former role in planning, through programs like the quasi-public "Sustainable Jersey" initiative, a voluntary municipal program that acknowledges and supports New Jersey cities and towns for implementing and maintaining various sustainability-oriented infrastructure, public works, and community-building initiatives (Sustainable Jersey, 2019). In sum, despite once being a central consideration in the waste management planning history of the state, data collected by state agencies measuring and describing the 'waste management problem' in New Jersey now plays only a supporting role in decisions about the future of waste management and recycling infrastructure.

In preparing this paper, we compared the NJ waste data with that available in other US states. Through internet search, we discovered a total of 42 out of the 50 states and the District of Columbia reported that they have a data collection system in place for waste data. It is possible the nine states that do not mention a data collection system actually do collect data, but do not advertise that information or make it publicly available. The nine states for which we could not locate solid waste data were Alaska, Arkansas, Idaho, Louisiana, Montana, North Dakota, Rhode Island, South Dakota, and Wyoming. Generally speaking, most of the states that do collect data produce annual or biennial solid waste reports that outline important new findings or major trends in quantity and waste type, reported at various geographic scales. In many instances, the depth of the dataset and the specific pieces of data being collected are not clear. For example, while New Jersey's data is very detailed with information collected down to the municipality level, Maine only reports state-wide data (Maine Department of Environmental Protection, 2017).

The US Environmental Protection Agency implemented a State Data Sharing Program (SMP) that uses the Re-TRAC Connect software. This program allows states to keep track of data related to Sustainable Materials Management all in the same place and have access to other states' data as well. There is no fee for states to participate in the SMP, but if a state wishes to use Re-TRAC to collect data within the state, a subscription fee is charged. This program can benefit states with collaboration and data sharing to compare, for example, the waste output in one state compared to others. This data is not openly available to the public at this time (US Environmental Protection Agency, 2015). As of August 2018, sixteen states used the Re-TRAC Connect software to collect their data, and were noted as paid subscribers. These states were Alabama, Florida, Georgia, Indiana, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Pennsylvania, South Carolina, Tennessee, Texas and Vermont. These states have reported significantly lower costs in data collection using the software (US Environmental Protection Agency, 2018b). In the future it may be beneficial not only financially, but collaboratively, for all states to collect data using the Re-TRAC system, which would offer states the opportunity to share data while also developing a country-wide data collection system.

3.2. Processing the 1993–2016 NJ waste dataset

In summer and fall of 2018, the project team worked with staff at the NJDEP Division of Solid and Hazardous Waste, Bureau of Solid Waste Planning and Licensing to determine the scope and formats of the historical waste and recycling data available about New Jersey. As explained in section 2 of this paper, it was ultimately determined that data covering the timeframe 1993–2016 was available and retrievable. The waste tonnage data consisted of multiple spreadsheets with numeric codes corresponding to the reporting month, waste type, county, facility, and municipality along with the tonnage reported. We learned that for waste tonnage data that had been entered manually, staff entered all information in a coded format for the categories above. For example, the data may originally have read "0101" to refer to municipality Absecon in Atlantic County, or "13C" to describe the category of construction and demolition waste. However, the meaning of the codes was not immediately apparent and required reference to a separate key document for explanations of each data type. Furthermore, many codes were inconsistent across data years. Therefore, one of our first tasks was to re-code all of the data we acquired in a uniform language that would allow any user to quickly and consistently identify what the data represents within the spreadsheet itself instead of having to look at a series of explanatory documents articulating what each code actually represented. As such our final dataset includes not only a consistent set of ID codes but corresponding referents inside the dataset itself. This would also prove to be a significant improvement for preparing the data for use in geospatial visualization software, as explained below.

A second major issue in preparing the data for analysis were gaps in reporting. In most data years, there were numerous instances where no disposal destination or waste type was reported. There were also instances numerous ID codes, especially destination facility, municipality of origin, and waste type, were reported as 'unknown', however tonnages were still reported. In order to account for the waste that came from an unknown source, a synthetic ID code NEDTIS ("Not Enough Data to Identify Source") was created. In some data years, NEDTIS disposal facilities or municipalities of origin represented significant amounts of solid waste tonnage – over four million tons in some years.

Creating uniform ID codes along with the synthetic ID code NEDTIS allowed us to significantly compress the quantity of individual waste tonnage records and size of the data files. For some data years, spreadsheets began with over 40,000 rows and were able to be consolidated into as few as 185 unique rows. The high number of entries in the original data was primarily due to the fact that much of the data would be reported monthly, meaning each disposal facility could have 12 separate entries for each municipality represented. Finding a mechanism by which we could condense this data was a very important step in terms of file size, legibility, and ultimately, usability by the public. We developed pivot tables within Excel in order to manipulate and summarize waste tonnage data without modifying the original entries (beyond cleaning them for consistency). For example, instead of having a dozens of entry rows for the town of Absecon, we used a pivot table to provide a total sum for each waste type, each year. We used the Excel software extension KuTools to aggregate total waste tonnages for each municipality as well as totals for each waste type within each municipality, county total tonnage, and destination facility tonnage for each waste type as well as overall total tonnage within each destination facility.

The recycling tonnage data, having been 'born digital' and managed by a single NJDEP staff member for over 20 years, was much more consistently organized. We encountered only minor inconsistencies across years which we attributed primarily to the transition of the data from the Microsoft Access database formats it had been originally collected and managed in, to the Excel format in which we had received the dataset. These inconsistencies were centered around ID codes for material type (e.g. aluminum, corrugated cardboard, newsprint, etc.) which in some instances were listed as a numeric code while others were abbreviated into a few letters. We resolved this issue by creating a master list of numerical codes and their abbreviated material name equivalents, and then wrote 'Nested If' statements allowing the simultaneous search of the dataset and replacement with a consistent code across data years.

The datasets are interesting and unique in that they allow users to estimate the amounts of material reported disposed at any licensed facility in New Jersey. Thus we imagined it would possible to link the origins of the waste stream in a given year to particular destination sites inside or outside New Jersey. One of the main purposes for requesting and processing the waste and recycling tonnage data was to visualize changes in the amount of waste material disposed in New Jersey over time using maps. Thus, preparing the 'raw' quantitative tonnage, type, and origin data for use in a GIS software was also a considerable component of our project. In order to spatially visualize the total tonnage of waste and recycling reported, at each facility, two steps were required. First, the facilities had to be geocoded using full address information. Then, the facilities had to be linked to the tonnage data for each year. In order to complete the first step, all of the facilities between 1994 and 2014 were collected into a single list, removing any duplicates and spelling errors so that each facility was a unique location. Some facilities required further merging upon discovering a name or company change at a location between years. The goal was to create a clear name field for each facility that indicated all previous company names or merging of companies. These names are represented with slashes (i.e. Alliance Landfill/Empire Landfill) so that each location will only appear once. A unique code was created for each facility for the purpose of simplicity in mapping, tables, and linking the facility addresses to tonnage tables. The code was created by using the first letter of each word in the facility name. Subsequent letters were used to avoid two facilities having the same code. If a company has more than one location, the code is followed by numerics (i.e. ACUA1, ACUA2, etc.).

Each facility location was found manually. A variety of sources were useful in finding addresses, such as Google Maps, court documents found online (usually cases between a landfill and the DEP or EPA), and company websites. Full address information, including street address, city, state, and country were recorded when available. Any facility that could not be located using any available source was again assigned the NEDTIS synthetic code. For example, in some tonnage records only the name of the state was given or "out of state", making it impossible to know where it came from. The cleanup resulted in a final table of 457 facilities with codes and addresses. Once every facility was located with full address information, the Excel table was imported into ArcGIS software and geocoded using ESRI World Geocoder. All facilities were matched with a spatial location, and 50 + random points were selected to ensure accurate placement of the facilities. A shapefile of the point facilities was created and is available along with the dataset itself.

In order to complete the second step linking the facilities to tonnage data, the shapefile of facilities and the tonnage data for each year would need to have a common field in order to link them spatially. The name of the facility in the solid waste tonnage tables could not be used accurately due to name/company changes, spelling errors, and other inconsistencies. Even one extra space or missing character results in missing/null data when linking an excel table to a spatial dataset. To create a common field, each yearly tonnage table was addressed manually and individually. Each facility and all of its entries were changed from their current name and spelling to the corresponding name in the facility key. For example, in 1994 and 1995, one entry might have read "A.C. utilities authority (camden)" while another read Atlantic City Utilities Authority (transfer station). Since the transfer station is in Camden, it was assumed that these are the same location simply written out differently. Both would be changed to match the facility key, Atlantic City UA (Transfer Station), and the code ACUA2. Because of so many discrepancies, making these types of changes could only have been done accurately by hand. Several other methods of find and replace with coding did not prove accurate and would have been just as time consuming to find all of the errors. However, once the name column of the tonnage tables was corrected, a script for find and replace on multiple inputs was used to link the codes to the name field which helped save time.

With the shapefile for the facilities completed and consistent facility names and codes in each year of solid waste tonnage, the final step in visualizing the data was to link them together. This was done by importing the data tables into ArcMap and using "join by attribute" and using the code field to link the code point locations to a tonnage amount. Further aggregation within Excel can be done depending on how the data will be displayed by users. We decided initially to use ESRI ArcMap to visualize the waste and recycling data, for many reasons. One was because ArcMap has a variety of ways that the tonnage data can be symbolized. Facilities with higher tonnage can be shown with a larger symbol or the data can be shown based on municipality, county, or state in a density map. Also, it is possible to map change over time. Since each year of tonnage uses the same facility codes, it is easy to link each year or future years together and show change over time (statically or with animation) and find emerging or diminishing hotspots. This is why it is extremely important that the codes in each tonnage table are consistent– without a consistent field, there would be no way to link the tonnage data to the address information or analyze patterns across tables.

4. Discussion

Examining historical waste management planning documents for New Jersey reveals that quantitative waste and recycling data were frequently used in modeling exercises to plan for future disposal facilities, incorporating a range of additional population and socioeconomic variables like average income, property value, and predominant housing type (e.g., Solid Waste Disposal Program; Division of Clean Air and Water; New Jersey State Department of Health, 1968; Camden County Planning Board, 1970; Planners Associates Inc. 1970; Division of Waste Management; NJ Department of Environmental Protection, 1985; Division of Solid Waste Management; New Jersey Department of Environmental Protection and Energy, 1993a). However, as we described in section 3.1 of this paper, since the early 1990s it appears that such direct incorporation of the quantitative data into waste management planning has decreased. This was surprising because prior to beginning our project, we had assumed, following the work of scholars like Bullock (2017), but also a range of voices representing the waste management industry itself (The Environmental Research & Education Foundation (EREF) 2016; Solid Waste Association of North America 2018), studying the waste management industry (e.g., van Haaren et al., 2010), reporting in specialized publications focused on the waste management industry (Rosengren, 2016, Hook and Reed, 2018, Rosengren, 2018b, c), and, especially, boosters of the prospects of 'big' datasets for addressing waste management and recycling problems (Mavropoulos, 2017a; b, 2018), that a large, robust, decades-long dataset recording several aspects of waste and recycling production and disposal would offer a number of avenues by which to analyze waste and environmental policy in New Jersey, and that we would find evidence of the dataset translated in some way to contemporary infrastructure on the ground.

However this is only partially true, especially when considering the 1993–2016 dataset in isolation. On one hand, the data by themselves make it possible to roughly trace flows of materials from their place of 'origin' – more accurately, where they enter the waste stream – to their place of 'destination' – or, again more accurately, where the State of New Jersey considers them to have reached a state of final disposal. The dataset also makes patterns of disposal clear, and shows how particular facilities increase or diminish in importance over time based on the amounts of material(s) they accept. This aspect of the data invites further exploration, possibly by linking changes in tipping fees, taxes, or policy directives (e.g., flow control, or mandating disposal at specific facilities) for waste, and changes in market prices for recyclable materials, to the volumes disposed at a given facility. In a similar fashion, the dataset is also valuable for the insights it offers into flows of waste and recyclables leaving New Jersey for other states, with materials reported as traveling as far away as New Mexico. Understanding the characteristics of waste and recycling "exports" like these is important if the trend towards out-of-state disposal continues to increase, perhaps especially in planning for the moment when out-of-state facilities or governments begin to exclude or limit imported materials – as New Jersey itself had done in the past.

With specific regard to the recycling data, which generally speaking has been much more meticulously maintained over the 1993–2016 timeframe, it is also possible to examine the impacts of state grantmaking programs and local initiatives on the recovery of different materials across New Jersey's many towns and cities. In other words, future studies using the dataset should be able to examine whether increases in grant money or other policy or educational interventions made a material impact on recycling in the state, at the scale of counties and individual municipalities (the recycling tonnage grant payout data has been reported since 2003; Division of Solid and Hazardous Waste, 2019b).

On the other hand, after cleaning and preparing the data for analysis and distribution, it is clear that there are a number of limits to what is possible. Some of this owes to inconsistencies in reporting and recording especially the waste tonnage data. We learned from interviewing current and former NJDEP staff that the state of New Jersey intended initially that waste haulers indicate the town of origin for any given load of material, which would have made a one-to-one relationship between the town wastes came from and their place of disposal. However, because in some instances a hauler might collect waste from several towns on a single route in the interest of efficiency, it could be impossible to know which wastes in the back of the truck came from which municipality. Yet over time, reporting this town-of-origin data point became a habit for those involved in data collection, even as it was understood to be somewhat unreliable. Several of our interview participants also pointed out that in many instances, the data reporting was seen as "just another" requirement imposed on municipalities and some disposal facilities by State government. These interview participants suggested that for some towns and facilities, especially those where budgets and staff were already stretched thin, the data submitted was likely littered with inaccuracies or sometimes just a re-submission of the previous year's (or month's) information. For the purposes of our project, we made the decision to accept the waste and recycling data at face value, as it was submitted to the NJDEP over time, but remaining aware of these limitations to the quality of the dataset.

As the preceding paragraph makes clear – and, as has been the case historically – the NJ waste dataset needs to be considered in conjunction with other socioeconomic and environmental data to be most useful. In particular, the waste and recycling data can be combined with a range of different demographic and socioeconomic data to better understand the relationships between recycling rates, solid waste disposal totals, and characteristics of cities and towns. We conducted a short regression analysis using US Census data in conjunction with this waste dataset that examines relationships between population, income, and waste disposal rates in two New Jersey counties; we have included this in the supplementary material published alongside this paper as an illustration of what is possible using the waste dataset in conjunction with other variables.

However useful it may be, in working to collect, clean up, and prepare for public use the 1993–2016 NJ waste dataset, we thought critically about the purpose of the dataset and the ways it might be used by the public. Based on project team members' experience working on solid waste policy research, it seemed clear that there would be a disconnect between what an average 'member of the public' might want to do with this data and the information the dataset actually contains. Waste disposal remains an intensely local issue in the US, handled at the level of the municipality or county, though it is clearly one with regional, national, and perhaps even global impacts. Many more people are interested in waste management, recycling, and composting issues than before – but a significant proportion of the NJ waste dataset would not be useful in answering the types of questions that many residents and small business owners frequently have: why does my service cost what it does? How is my town assessing bids for contractors? Why can I (not) recycle certain materials in my town, but in the next town over, they do (don't) without issue? How do forecasts derived from the waste data collected by the state actually translate into plans for constructing a transfer station or disposal facility, and how can I use the waste dataset to support (oppose) such a plan? What happens if (when) out-of-state shipments of waste are no longer possible for political or economic reasons?

The public, government officials, or other researchers might look to the NJ waste dataset as a starting point for answers to these types of questions, but leave frustrated or confused. This is understandable given recent 'hype' surrounding data-intensive proposals for enhancing the ecological and economic performance of waste management systems. For instance, the president of the International Solid Waste Association (ISWA, which reports nearly 100,000 members in the waste and recycling industry worldwide; 2019, n.p.), Antonis Mavropoulos writes regularly in his official blog about how data collected automatically from bin- and dumpster-based sensors will revolutionize waste collection and sorting practices: "…data includes duplicates and irrelevant noise, but there are a lot of relevant information that is secured and analyzed. This results in knowledge that leads to actions and decisions…In the future these datasets can be exploited in new ways to improve the services or for research in new fields." (e.g., Mavropoulos, 2017a, n.p.) Blockchain-based tools are purported to revolutionize the ways in which an "internet of materials" communicates and operates to enhance recycling operations (Mavropoulos, 2018). Most directly, Mavropoulos writes with Jason Gates (CEO of a waste data gathering firm, Compology) that "Zero Waste Needs Big Data":

> There's a shift happening in the way we, as individuals and collectively, think about minimizing our impact on our environment. Financial, political and environmental pressures are putting an increasing emphasis on consumers, businesses and governments to be more efficient, produce less waste and handle the waste we do generate more effectively. We see this across all industries, through increasing commitments to sustainable practices, and across all levels of government, through increasing numbers of environmentally-focused programs and mandates.
>
> As a result, businesses and governments have rightfully turned to technology to aid sustainability and efficiency efforts…Where the industry has lacked technology, until now, is around collection of real-time information on the fullness, location and contents of waste containers. This lack of container information has limited the ability of waste haulers, waste generators and municipalities to operate more efficiently and take on the complex challenges of recycling and diversion efforts. Without a way to gather more information on generator habits and how haulers currently operate, gaining transparency and making impactful decisions for the future remains difficult. (Mavropoulos, 2017b, n.p.)

5. Conclusions

The New Jersey waste dataset, which is better than most, is a considerable distance from the scenario Mavropoulos and Gates describe. There remain significant gaps in both the type of data collected and the ways in which it is able to be used, which inhibit the ability of planners to design and implement comprehensive waste management plans. This is due primarily to a mismatch between what the state's waste and recycling data gathering infrastructure is designed to do and the decisions it is (or was, historically) intended to inform, and what many zero waste and waste management data boosters think is possible.

The considerable gap between the possibilities of future data-driven waste and recycling infrastructures and the present-day realities of data collection and analysis capacity have been considered by other researchers. We choose to return to the work of Offenhuber, who writes:

> "Even within the waste management community, one finds vastly different perspectives and agendas for composting, recycling, landfilling, waste- to-energy, or zero-waste. Not only do these approaches perceive waste as different kinds of problems, they use different toolsets for conceptualizing, observing, and representing the system. Epidemiologists, for instance, are concerned with spatial distributions of disease and medical pathways while engineers look at material flows and system performance…Each input can be tweaked to achieve different outcomes that serve as a basis for decisions. By allowing different outcomes, each prescribes a specific perspective that offers a partial view of the system." (2017, 9–10)

We must understand how the data collection systems we have function, and how well they describe the salient features of the infrastructures they are intended to observe and measure. In this paper, we presented our work on New Jersey's waste and recycling data collected between 1993-2016 not simply to illustrate an instance of the complicated and time-consuming process of locating, cleaning, and using 'big' environmental data. Instead, we offered this as both a case study and an entrée into larger questions about the value of environmental datasets to the general public, and as a way to point to the persistent disconnection between greater knowledge about an environmental issue (in this case, solid waste management) and meaningful action to address that issue. We leave readers with three questions that we were unable to answer, but that articulate pathways for additional study beyond this initial paper: first, even if made available through websites or other straightforward requests, is raw data about environmental phenomena truly valuable and more importantly, useful, in shaping public understanding about an issue and determining the appropriateness of a response to that issue? Second, do public entities have an obligation to present data in a way that is readily usable to those without the time and/or know how to process it? Third, and finally, we wonder: in examining the successes and limitations of the NJ waste dataset, what is waste management data for?

It may be the case that a 'data revolution' is coming for the waste and recycling sector. But clearly there are more fundamental concerns that must be addressed first, before any meaningful advanced data analysis can take place. For instance, reported on almost as frequently as the prospects for big data, real-time reporting, and similar speculations, is the reality that there are no common guidelines for collecting and reporting data about waste and recycling (e.g., Rosengren, 2018c). In the US at least, definitions of waste vary by state and even by county, making geographic comparisons challenging, and rectifying this basic attribute of effective data gathering – consistent reporting – seems far more important than putting cameras and wifi sensors in trash bins around the world. To this end, since at least 2008, regional US EPA officials have been building the Measurement Matters network to harmonize data collection and reporting (Measurement Matters, 2019), and in 2018 the US EPA announced efforts to make recycling and materials reporting more consistent nationally (Rosengren, 2018a; US Environmental Protection Agency, 2018a).

Declarations

Author contribution statement

Jordan Howell, Katherine Schmidt, Brooke Iacone, Giavanni Rizzo, Christina Parrilla: Conceived and designed the project; Performed the project; Analyzed and interpreted the data; Contributed, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by the National Science Foundation - Science, Technology & Society Program (grant number 1733924); and the Rowan University School of Earth & Environment Dean's Fund for Student Research.

Competing interest statement

The authors declare no conflict of interest.

Additional information

Data associated with this study has been deposited at Mendeley Data at the https://doi.org/10.17632/7yc4c3pmtp.2. Included in the supplementary materials are several files: 1) An overview essay ("01_Overview of Supplementary Materials") 2) A brief illustration of the type of regression analysis that other users are able to undertake with the dataset ("02_Regression Supplementary Essay") 3) The complete 1994-2015 Solid Waste Tonnage dataset ("SW Tonnages" folder) according to municipal totals ("Muni Totals" folder) and destination disposal facility totals ("Destination Facility Totals" folder) 4) The complete 1995-2015 Recycling type/tonnage data produced in accordance with the New Jersey Recycling Tonnage Grant program ("Recycling Tonnages" folder) 5) ESRI ArcGIS spatial files (including shapefiles) plotting facility locations ("GIS data" folder) along with key to facility location coding ("03_Disposal Facility Key")

Acknowledgements

Thanks to Carlton Dudley and Connor Loftus at the New Jersey Department of Environmental Protection (NJDEP) for facilitating collection and distribution of the waste and recycling tonnage data. Thanks also to Joe Davis, formerly administrator of the NJDEP recycling grants program, and Gary Sondermeyer, formerly chief of staff at NJDEP, for helping our research group organize and understand the limits of the dataset.

References

Bullock, Graham., 2017. Green Grades: Can Information Save the Earth? The MIT Press, Cambridge, MA.
Camden County Planning Board, 1970. Solid Waste, 1970. Camden County Planning Board, Pennsauken, NJ.
Commission to Study the Problem of Solid Waste Disposal, 1965. Public Hearing before Commission to Study the Problem of Waste Disposal: (Created under Provisions of Assembly Concurrent Resolution No. 36). New Jersey Legislature, Trenton, NJ.
Division of Solid and Hazardous Waste, 2019a. New Jersey Generation, Disposal, and Recycling Statistics. New Jersey Department of Environmental Protection accessed 12 April. https://www.nj.gov/dep/dshw/recycling/stats.htm.
Division of Solid and Hazardous Waste, 2019b. Recycling Tonnage Grant Payout Schedule. New Jersey Department of Environmental Protection accessed 12 April. https://www.nj.gov/dep/dshw/recycling/stats.htm.
Division of Solid Waste Management; New Jersey Department of Environmental Protection and Energy, 1993a. Draft New Jersey State Solid Waste Management Plan Update 1993–2002, Section I: Municipal and Industrial Solid Waste. New Jersey Department of Environmental Protection and Energy, Trenton, NJ.
Division of Solid Waste Management; New Jersey Department of Environmental Protection and Energy, 1993b. Solid Waste Management State Plan Update, 1993–2002 - Draft. New Jersey Department of Environmental Protection and Energy, Trenton, NJ.
Division of Waste Management; NJ Department of Environmental Protection, 1985. Solid Waste Management Plan: Draft Update, 1985–2000. New Jersey Department of Environmental Protection, Trenton, NJ.
The Environmental Research & Education Foundation (EREF), 2016. MSW Management in the U.S.: 2010 & 2013. Raleigh, NC.
Hook, Leslie, Reed, John, 2018. Why the World's Recycling System Stopped Working. Financial Times, 25 October.
International Solid Waste Association, 2019. About ISWA accessed 15 April. https://www.iswa.org/iswa/organisation/about-iswa/.
John J. Bergin, and Office of the Deputy Attorney General, 1959. Garbage Collection Practices. Office of the Attorney General, Trenton, NJ.

MacBride, Samantha, 2012. Recycling Reconsidered: the Present Failure and Future Promise of Environmental Action in the United States, Urban and Industrial Environments. MIT Press, Cambridge, MA.

Maine Department of Environmental Protection, 2017. Maine Solid Waste Generation and Disposal Capacity Report: Calendar Year 2015 accessed 13 April. https://www.maine.gov/decd/meocd/landfills/docs/Waste_CapacityReport%202017.pdf.

Mavropoulos, Antonis, 2017a. Digitising Waste Management: the Rise of Big Data Sets accessed 1 October. https://wastelessfuture.com/digitising-waste-management-the-rise-of-big-data-sets/.

Mavropoulos, Antonis, 2017b. Zero Waste Needs Big Data accessed 1 October. https://wastelessfuture.com/zero-waste-needs-big-data/.

Mavropoulos, Antonis, 2018. Blockchain Stimulates the Internet of Materials accessed 1 October. https://wastelessfuture.com/blockchain-stimulates-the-internet-of-materials/.

Measurement Matters, 2019. About Us accessed 15 April. http://www.measurementmatters.net/about-us-2/.

Melosi, Martin V., 2000. The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present, Creating the North American Landscape. Johns Hopkins University Press, Baltimore, MD.

Melosi, Martin V., 2005. Garbage in the Cities: Refuse, Reform, and the Environment, Rev. ed. In: History of the Urban Environment. University of Pittsburgh Press, Pittsburgh, PA.

Mercer County Planning Board, 1971. Mercer County, New Jersey Comprehensive Plan: Solid Waste Disposal Study and Plan. Day & Zimmermann, Inc, Philadelphia, PA.

Monmouth County Planning Board, 1966. Study & Plan of Refuse Collection and Disposal, Monmouth County: Monmouth County Board of Chosen Freeholders.

Musto, William V., The County and Municipal Government Study Commission, 1972. Solid Waste: A Coordinated Approach. County and Municipal Government Study Commission, Trenton, NJ.

New Jersey Advisory Committee on Recycling, 1980a. Recycling in the 1980's: the Report on Recycling in New Jersey. Office of Recycling, New Jersey Department of Environmental Protection, Newark, NJ.

New Jersey Advisory Committee on Recycling, 1980b. State of New Jersey Draft Plan on Recycling. New Jersey Department of Energy and New Jersey Department of Environmental Protection, Trenton, NJ.

New Jersey Department of Environmental Protection, 2006. Statewide Solid Waste Management Plan. New Jersey Department of Environmental Protection, Trenton, NJ.

Offenhuber, Dietmar, 2017. Waste Is Information: Infrastructure Legibility and Governance. The MIT Press, Cambridge, MA.

Offenhuber, Dietmar, Ratti, Carlo, 2014. Decoding the City: Urbanism in the Age of Big Data. Birkhäuser (De Gruyter, Basel, Switzerland.

Office of Recycling; Division of Waste Management; NJ Department of Environmental Protection, 1984. Recycling in the 1980's: Progress Report and Program Recommendations. New Jersey Department of Environmental Protection, Newark, NJ.

Office of Recycling; Division of Waste Management; NJ Department of Environmental Protection, 1986. A Guide to Marketing Recylable Materials. New Jersey Department of Environmental Protection, Trenton, NJ.

Perrotta, Frank, 1969. An Updated Study of Bergen County's Solid Waste Disposal System. Bergen County Board of Chosen Freeholders, Hackensack, N.J., 1969.

Planners Associates Inc, 1970. New Jersey State Solid Waste Management Plan. Planners Associates Inc. and Bureau of Solid Waste Management, New Jersey Department of Environmental Protection, Newark, NJ.

Rosengren, Cole, 2016. EREF vs. EPA: How Varying Statistics Indicate a Need for Standardized Reporting Industrywide. Waste Dive, 5 October.

Rosengren, Cole, 2018a. EPA's Wheeler and 44 Others Pledge to Create a 'more Resilient Materials Economy. Waste Dive, 16 November.

Rosengren, Cole, 2018b. Rubicon's Smart Cities Program Expands to More than 20 Locations. Waste Dive, 27 April.

Rosengren, Cole, 2018c. Will There Ever Be One Standard Recycling Measurement? Waste Dive, 28 August.

Solid Waste Disposal Program; Division of Clean Air and Water; New Jersey State Department of Health, 1968. The New Jersey Solid Waste Disposal Program. Trenton, NJ.

Special Legislative Commission to Investigate Certain Problems Relating to Solid Waste Disposal, 1969. Public Hearing before Special (Legislative) Commission to Investigate Certain Problems Related to Solid Waste Disposal (Constituted under SCR 24 of 1969), Vol. 2. New Jersey Legislature, Trenton, NJ.

Sustainable Jersey, 2019. About Us accessed 11 April. http://www.sustainablejersey.com/about/.

Solid Waste Association of North America, 2018. T-6.4 SWANA Technical Policy: Measuring Recycling. Silver Spring, MD.

Tocks Island Regional Advisory Council, Candeub Fleissig & Associates, 1969. Tocks Island Regional Interstate Solid Waste Management Study. Tocks Island Regional Advisory Council, Stroudsburg, PA.

US Environmental Protection Agency, 2015. Resources for Participating in the U.S. State Data Measurement Sharing Program accessed 29 March. https://www.epa.gov/smm/resources-participating-us-state-data-measurement-sharing-program.

US Environmental Protection Agency, 2018a. EPA Celebrates America Recycles Day, Convenes Recycling Summit to Strengthen Domestic Recycling.

US Environmental Protection Agency, 2018b. Frequently Asked Questions (FAQs) accessed 29 March. https://www.epa.gov/sites/production/files/2018-10/documents/smp_faqs_2018_final.pdf.

van Haaren, Rob, Themelis, Nickolas, Goldstein, Nora, 2010. The State of Garbage in America. BioCycle. October, n.p.