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Review Article

Sustainable Municipal Solid Waste Management Data Analytics Driven Perspective

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Abstract

This paper coins the concept of data-driven municipal solid waste management (DDMSWM). The waste sector aims to achieve goals such as reduction, reuse, recycling, recovery, and disposal of waste for the preservation of natural and built environments, including energy, climate, and water and soil resources. Our original concept distinguishes between DDMSWM and traditional sustainable materials management. The latter term refers to matters that are sent to the landfill or municipal combustors.

The municipal solid waste (MSW) industry (MSWI) collects massive amounts of heterogeneous and unpredictable waste-related data to analyze and, accordingly, make management and operational decisions. This paper debates some strategic issues of the MSWI's data-related practices, such as the following: 1. The modern world is rapidly changing, with an unpredictable future. Who could have imagined the recent international waste-related new policies, epidemics, conflicts, and the state of the economy, just to name a few examples? At the national [1], state [2], and county [3] levels, the US Centers for Disease Control and Prevention (CDC) collected the COVID-19 data and aggregated it on a weekly basis because of the unpredictability issue. The logical question is thus: can the massive amounts of seasonably collected MSW data from the modern world be relied upon for making long-term strategies? The approach of the MSWI to data exploration needs to be reconsidered starting from its foundation, i.e., data. 2. The previously mentioned collected MSW data and its quantitative judgments suggest the MSWI pays attention to the understanding of various facets of waste such as composition, characterization, rates, generation, and differences. On the one hand, the disseminated outcomes obtained from the MSW collected data [4,7-13] clearly show the complex and diverse inherited characteristics of the MSW data. On the other hand, the same literature suggests the use of simple conventional analytic tools to analyze that kind of data. The logical question is: by putting the two hands together, what is the significance of the outcomes disseminated for industrial MSW practices? In addition, in today's economically stressed MSWI [4] and a world that runs on live streaming technologies, can the MSWI afford to continue doing business-as-usual? 3. The same literature suggests the MSWI is paying attention to trends in waste-related goals, e.g., zero waste, efficient waste collection, waste reduction, recycling, and resource recovery. The logical question is: how can the goals of the US's Federal Resource Conservation Act (RCRA) [5] and New York State Municipal Solid Waste (MSW) [6-8] frameworks, plans, acts, and other goals be achieved using simple conventional numerical data manipulation?

There are other relevant questions than the above to ask and observations to note. However, Albert Einstein once said, "In the middle of difficulty lies an opportunity". Whether the collected data and generated outcomes indicate a favorable trend [7-12] or not, the MSWI must adapt its analytic tools to today's world and technologies rather than a world that no longer exists. Our vision ensures that viable decisions are made in response to the unprecedented challenges as they occur.

A key objective of this paper is to introduce a systematic review of the futuristic concept of data-analytics-driven robust DDMSWM to the MSWI, in general, to benefit from the corporations that have been on the data-driven technology path and to revamp its practices.

Keywords: Data Analytics; Data Science; Municipal Waste; Waste Management; Resource Recovery; Recycling; STEM

Background

The New York State Department of Environmental Conservation's (NYSDEC) "Beyond Waste" plan [8] instituted seventeen strategic goals for "sustainable materials management". The Onondaga County Resource Recovery Agent (OCRRA) recently disseminated a valuable literature on the collected data but using, apparently, basic conventional analytic tools [9-13]. Because at the time of developing those statistics, no one could even imagine the state of modern data analytics (DA). One may wonder about the undetected facts in those meritorious reports. This observation calls for urgent corrective actions to be taken to adjoin data-related waste practices to all the top corporations in the USA that run on DA for viability and sustainability. The list of names is long and includes [14,15]. Google, Facebook, Apple, Amazon, Starbucks, Bristol Myers-Squibb, just to name a few examples. Because municipalities strive to optimize extracting values from waste, identifying areas for improvement in current frameworks will help the MSWI achieve its goals. The MSWI wouldn't have lagged other corporations if it weren't for its use of simple conventional analytic methods.

The MSWI recognizes the benefits of data-driven decision procedures but seemingly does not currently have a known strategy, or framework, or plan to implement the most recognized modern technologies, i.e., DA. The available literature [9-13] suggests sufficiently waste-related large data sets in quantity, variety, and complexity, yet there is a gap between their quantification methods and modern practices. The MSWI needs to focus on the first step any organization takes, i.e., analysis of data, before considering further steps such as minimization or maximization, increasing or decreasing, creating or advancing, engaging, or fostering the identified outcomes. This paper brings a fresh set of eyes to the MSWI in general. The following sections explore various facets of DA, challenges, and opportunities for implementing the technologies in the MSWI.

What is data analytics?

Data analytics encompasses the qualitative process of analyzing complex data sets for the extraction of insights. DA is an all-in-one tool rather than a one-size-fits-all tool. Without doubt, it has revolutionized all other industrial fields as well. Volume, variety, and velocity are the key features that distinguish data sets. Data with a high velocity indicates near real-time collection and integration of information, and data with a high variety implies heterogeneity in the structure and type of data stored. So, it is no surprise that these features render basic conventional data analysis techniques inappropriate for modern challenges. As previously mentioned, the viability of the top corporations depends on DA's wading through the data tsunamis. To this end, the following two common models are adequate for DDMSWM.

Predictive analytics to identify trends and predictions about waste generation.

Performance analytics to assess detailed performance metrics.

Data analytics driven integrated approach for MSWI

All the available MSW data-related literature suggests using the massive amounts of collected data and basic conventional methods for analysis of the overly complex data. Now that the world has explored and validated DA's powerful capabilities, the time has come to deviate from the business-as-usual approach to modernize, if not revolutionize, industrial data-related practices. Our revamping vision is simple: don't reinvent the wheel, but reforge it. Today's world and challenges are different from those that existed even a few years ago. For example, data analytics technologies were not as common in everyday industrial applications as they are nowadays. Via his relevant expertise [16-22], this author suggests a revamping perspective to the existing MSWI, starting with capacity building, including the following.

The development and dissemination of guidelines to benefit the MSWI.

Training sessions for those already in the workforce to revamp their skills.

Encourage and assist the schoolers who are the seeds of the next generation of industrial leaders to consider DA for acquiring a life-long industrial career. In this regard, data science has massive data in common with DA. Data analytics is essentially a special application of data science in which the datasets are massive and require overcoming logistical challenges to deal with them. STEM stands for Science, Technology, Engineering, and Mathematics. We envisioned [22] a trifold DA-STEM-MSW incubator for developing a workforce capable of converting massive MSW data into practical benefits. Python, as a coding language, has many advantages, including being open-source and free, being easy to intuitively learn,

having an excellent online community, integrating well with other packages, and being faster than similar tools such as R and Matlab.

Outreach to the forward-thinking stakeholders who are concerned about the impact of MSW on the future of the MSWI.

Conclusions

Humans live in a material world, and there will be waste as long as they live. How humans use materials is vital to the sustainability of our planet. Thus, sustainable use of materials and municipal solid waste are inseparable. Data and waste are two faces of the same coin. We need waste to generate data and need data to manage the waste. In a world that is rapidly changing with an unpredictable trajectory, it is sufficiently clear that the MSWI needs modern data-driven decision systems. This paper discussed the case of why modern data analytics technologies for the MSWI are the central pole for the DDMSWM future. The paper innovatively conceptualized a viable modernization agenda for DDMSWM in the context of MSWI. Whether or not the massive amounts of collected and analyzed waste data indicate improvement, the methods used in today's MSWI for data analysis are basic and need to be revamped. As Albert Einstein once said, you cannot keep doing the same thing and expect a different result. Data analytics provides guaranteed success in revamping the MSWI, as it did for the most successful corporations in the world.

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