Assessment of the Wasteaware Indicator for Selected Cities in the US and China

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Table of Contents

Abbreviation

ISWM-Integrated sustainable waste management
MSW-Municipal Solid Waste
WTE-Waste to energy
US-United States

Abstract

This study uses the 'wasteaware' indicator to compare the waste management performance of selected cities in the US and China. The rates of waste management disposition in the US has remained the same since the late 1990s. In 2011, 63.5% of the waste was landfilled, 29% of the waste was either recycled or composited and 7.6% was sent to waste to energy facilities. In China about 35% of the waste was combusted for energy and around 5%-10% was recycled. Around 60% of the waste was sent to landfills. (Shin, 2014)The indicator used in the analysis, integrates six dimensions for evaluating the systems with different backgrounds. Three dimensions are for quantitative analysis purposes, they focus on the physical drives of the systems: public health, environment disposal, and resource recovery. The other three components mainly focus on the governance aspect - inclusivity, financial sustainability, and sound institution and proactive policies. The comparative analysis looks first at waste generation rates and wastes composition rate. A radar diagram is prepared for each city as a powerful tool to evaluate the solid waste system in a comprehensive way. The traffic light coding system is applied to visualize the results. By using the indicator set, the reference cities in the US and China with significant differences in the income levels and policy backgrounds become comparable. The cities selected in China are capital and regional capital cities. They have had relatively sophisticated systems but are still seeking innovation, such as improving incineration and energy recovery processes to increase the thermal efficiency. The cities in the US heavily rely on the current systems, whereas innovation is rare. For the future improvement of systems, it is recommended that China should put more effort into the quality of the system performance and the US should adopt policies to encourage the waste to energy recovery.

1.0 Introduction

Solid waste management is one of the most important functions of a city, it contributes to the basic function of a city's government. On the one hand, the efficiency of a management system affects the public health, the residence is exposed to unprotected dangers, on the other hand, the external image of a city depends on a good solid waste management. It attracts tourist and business investors and consequently brings economic benefits to the city. The effectiveness of a city's solid waste management system has been suggested as an indicator of a good governance and hence of a city which is livable and investable.

China and the US, these two countries are always compared. Both of two countries have formed a unitary system on waste management. Governments put efforts on optimizing its current waste management systems. In China, the government is trying to restructure the current disposal pyramid. They are still using comparably traditional disposal methods in recent years, but start to convert the disposal method from landfill to energy recovery by building recovery plants. In 2016, 63% of the municipal solid waste is disposed by landfill and around 35.1% of the waste is disposed by thermal treatment and burning. However, the data that the government posted in the public database is limited. In the US, currently there is no federal regulations that encourage municipal solid waste as a source of renewable energy and only 23 states have waste to energy plants. (Cheng, 2017)

Solid waste management systems in these two countries are always compared, however, the basic kinds of information are collected in different ways. The indexes of the management indicators in these two countries are not consistent in a global scope, which means the data from two countries are not comparable. In order to give a more accurate comparison result, integrated solid waste management (ISWM) benchmark indicator is introduced in this paper and gives the indicator users a uniform standard when they try to qualify the management system again. The indicator is appropriate for not only high-income countries but also in developing countries. It has been applied to 20 "representative" cities across the six in habitat continence, with diverse income levels. The new data collected by the collaboration team from the 20 cities contributed to a very impressive practice and result. The 20 "representative" cities also included two cities from the US and one city from China. This indicator is therefore selected as the only one standard in this paper to collect and compare the data from other cities in the US and China (Wilson D. C., 2012).

This paper presents the results of a comparative analysis of cities in the US and China, using the new data collected from the collaborated institutions to compare the solid waste management system in these two countries. Integrated sustainable waste management (ISWM) benchmark indicator is applied to the cities as a standard methodology
This is important to allow cities in China and the US to find the differences under two social policies and to learn from each other.

2.0 Methodology

2.1The framework of analysis

The analysis framework is built around the concept of integrated solid waste management system, as be known as ISWM benchmark indicator. The ISWM framework distinguishes three dimensions for analysis of solid waste management and recycling systems: The physical system and its technological components, sustainability aspects (social, institutional, political, financial, economic, environmental and technical) and the related stakeholders involved.
The ISWM benchmark indicator is created to fit both situations of the high-income country and developing country. All of the basic indicators in the ISWM indicator set is available for most of the cities around the world. It relieves the inaccurate comparisons between cities due to the unreliable and inconsistent data.

The ISWM system is divided into two triangles for a better understanding purpose. The first triangle is also known as physical "hardware" component, includes three key drivers for the development of solid waste management. These three key drivers are public health, waste treatment, and disposal and resource management. The second triangle includes the "software" components, it mainly focuses on the government strategies of system development. (Wilson D. , 2014)This triangle is more like a quality evaluation of the system, it shows the impacts of politics, economics, and institutions. The governance aspect includes inclusivity, financial sustainability and the attendance of sound institutions and pro-active policies.

In general, the ISWM system is designed to better analyze the solid waste management system in varied background cities. Its derived products ISWM benchmark indicator can be used to quantify the waste management system.

(Wilson D. C., 2012)

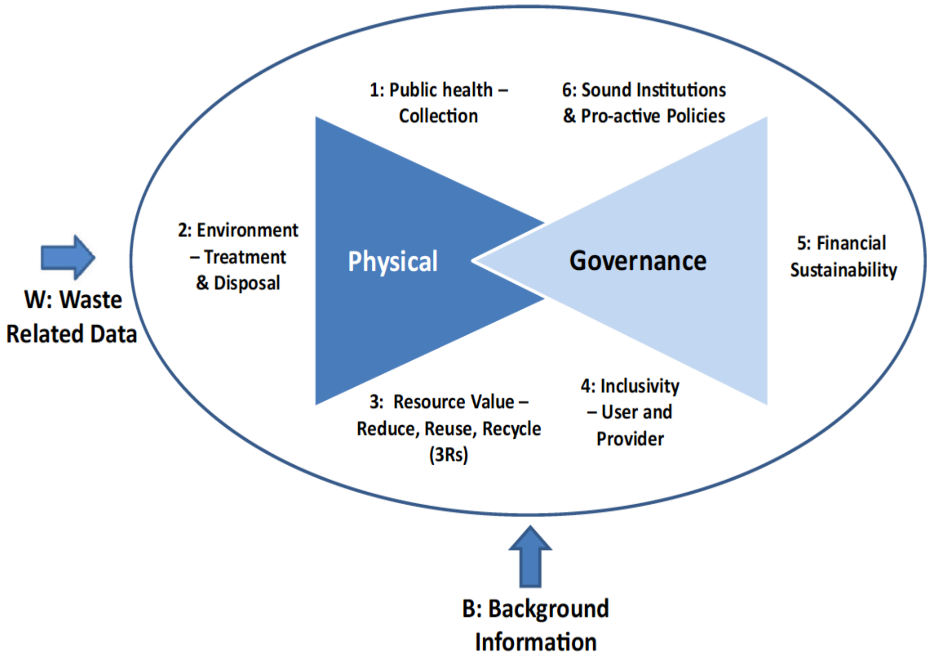

Figure 1ISWM framework

In order to make the comparison between China and the US possible, the methodology, as described in Wilson et al., 2012, was used. Seven benchmark indicators were developed, as a result of 300 characteristics that relate to a city's waste management system and associate with the three key drivers of the system and the three governance strategies which affect the sustainability of the system. The indicators can be applied to cities in low- lower-middle, upper-middle income level countries.

2.2 City selection and data collection

A set of criteria was established for the selection of the reference cities:

- size, from mega-city （with population in excess of 10 million) to town (with population between 1000-20000)
- cities with different income levels

The city should:

- give a good illustration of one or more points of interest;
- have an administration and other stakeholders willing to participate, prepare the materials, provide information and share both good and not-so-good experiences; (Wilson D. C., 2012)

We originally planned to select four reference cities from four income levels in each country, however, some of the administrations only have limited time to read the indicator instruction and complete the indicator form. The final selected reference cities are Beijing and Zhengzhou in China, and New York and Palm Beach, Florida in the US. The geographic locations of these cities are displayed on the map in figure 1, and some background data are in table 2.

The selected cities in China and the US are both distributed in the eastern plain of the continent. The cities include mega-cities, Beijing and New York, with 21 million and 8 million people accordingly and touristic city Palm beach county, with less than 1471000 people. (Barron, 2018)

China is defined as a lower-middle income level country and the US is defined as a high-income level country according to its gross national income (GNI/capita) by using the World Bank's grouping. UNDP's human development index (HDI) is also reported in the table. The US has a higher HDI (0.954) than China (0.772), which means the US has a higher average living standard.

Two reference cities in China are both national or regional capital. Beijing is the national capital of China and Zhengzhou is the regional capital of Henan province. They are all inland cities, unlike New York and Palm Beach.

Table 1 The reference cities

Country	State	City	Country Characteristics				City Characteristics				
			Income category	GNI capity	HDI	Population	Area (mi^2)	Population density (per mi^2)	Population growth (%)	Regional or national capital	Coastal or island location
USA	NY	New York	high	48460	0.964	582949	302.6	27000	4.6	R	C
USA	Florida	Palm Beach	high	48460	0.964	582949	2383	747	1.20	/	C
China	Beijing	Beijing	Lower-middle	3650	0.772	3500000	6490	3359	2.12	N	/
China	Henan	Zhengzhou	Lower-middle	3650	0.772	3500000	2875	3328	3.93	R	/

Figure 2 Map showing the location of the 4 reference cities

In the very early stage when the indicator set was born, four of the indicators are quantitative indicators, which means they are derived from the real data brought by the management system. The remaining three indicators, which mostly relate to the governance strategies, are qualitative indicators. However, these seven indicators in one set all became qualitative indicators in the late stage. This change makes the comparison between the results simpler and more intuitive.

The most serious test facing the previous similar research is the data collected from cities are inconsistent and inaccurate. Some of the data are from a second-hand dataset or even oral information. Even within one country with uniform regulations, culture and government documents, benchmarking of solid waste management system still facing barriers. In order to eliminate the bias come from the data, the ISWM indicator stipulated that each city must arrange a special indicator user, who is similar with the city and knows the situations of the solid waste system in that city well, to complete the assessment. The indicator users are not required to have the same professional background in environmental science, but they are encouraged to provide a variety of perspectives. In this research, the indicator instruction was translated to Chinese to ensure the content is understood in the same way across cities.

Table 2 Definition of physical indicators

Physical indicator			
Analytical criteria	Public health	Environmental control	Resource management
Indicators	Waste collection and sweeping coverage	Controlled disposal	Materials recycled or recovered (valorized)
Description	%percentage of households who have access this service	Quantitative percentage of waste goes to: engineering landfill, a controlled disposal site or a type of controlled treatment, including thermal treatment	Quantitative percentage of total waste which is recycled as material: both dry material (glass, metals, paper, plastics,etc.) and organic recovery (composting, anaerobic digestion, animal feeding) are included

	% of waste generate is collected and delivered to an official facility		

Table 3 Definiations of Governance Indicators

Governance indicator				
Analytical criteria	Inclusivity		Financial sustainability	Institutional coherence
Indicators	Degree of user inclusivity	Degree of provider inclusivity	Population using and paying for collection	Acquittance of national framework/and local institute coherence
Data request	Composite score on a set of quality indicators allowing a yes for present and a no for absent. Represents the degree to which users of the solid waste services (i.e. households, business and other waste generators) are included in the planning, policy formation, implementation and evaluation of those services.	Same score rule as user inclusivity. Represents the degree to which non-municipal waste service providers from the formal private, community or informal sectors are included in the planning and implementation of solid waste and recycling services and activities.	Quantitative percentage of total households both using and paying for waste collection service	First four indicator assess policy and the degree of municipal control The remaining two indicators assess the degree to which the solid waste budget is directly controlled by one responsible department within the city, and the degree of management control over WM which that department has.

2.4 The radar diagram and traffic light coding system

The radar diagram is used as the data comparison and analysis method for a concise presentation to identify a city's solid waste and recycling system. It gives a total picture of a solid waste system at a glance. In this way, the weakness and strength of the system are easily identified. The radar diagrams of each city can be combined into one diagram, the comparison between cities are therefore easy to access and the reader's attention will be drawn to the area of potential improvements of a specific city.

Assessing the solid waste management system in a city by using the ISWM benchmark indicators not only gathering the basic values of the four quantitative indicators but also recording the data under sub-indicators that used to calculate the final results and the resource where the personal judgment comes from. A traffic light color coding system is used in the summary page which can show the result more intuitive to international decision makers and agencies.

3.0 Analysis

3.1Comparing cities

The data presented in the table are from the summary page of the indicator form.

Table 4Summary results for the Wasteaware ISWM benchmark indicators in four reference cities

			Results			
City			New York	Beijing	Zhengzhou	Palm Beach
Country			US	China	China	US
B1	Country income category	World Bank income category ($)	64540 High	7641 Lower-middle	4932 Lower-middle	33610 High
B2	Population	Total population of the city	8623000	21730000	9881000	1410000
B3	Waste Generation	Total municipal Solid Waste generation(tonnes/year)	4562500	9010000	2555000	1745253
NO	category	data/benchmark indicator				
Key waste-related data		Data				
W1	waste per capita	MSW per capital (Kg/year)	529.108199	414.63415	258	1237.7681
		MSW per capital (Kg/day)	1.45	1.09	0.98	3.3911454
W2	Waste composition	Summary composition of MSW for 3 key fractions-all as %wt. of total waste generation				
W2.1	organic	Organics(food and green wastes)	47	60	64.75	33.5
W2.2	paper	Paper	23	17	3.22	25.4
W2.3	plastics	Plastics	14	18	6.67	14.7
W2.4	metals	Metals	4	0.5	2.21	1.95
Physical components		Benchmark indicator				
1	Pulic health-waste collection	1.1Waste collection coverage	100%	90%	95%	100%
		1.2Waste captured by the system	100%	95%	95%	100%
1C		Quality of waste collection service	91%	92%	65%	99%
2	Environmental control-waste treatment and disposal	Controlled treatment and disposal	100%	100%	95%	100%
2E		Quality of environment protection of waste treatment and disposal	100%	80%	70%	100%
3	Resource value-3Rs:reduce,reuse, recycle	Recycling rate	47%	45%	35%	72%
3R		Quality of 3Rs-Reduce, reuse recycle-provision	60%	35%	40%	80%
Governance Factors		Benchmark indicator				
4U	inclusivity	User inclusivity	95%	50%	90%	95%
4P		Provider inclusivity	50%	10%	30%	95%
5F	Financial systainability	Financial sustainability	100%	95%	50%	100%
6N	Sound institutions proactive policies	Adequacy of naional solid waste management framework	100%	93%	88%	100%
6L		Local institutional coherence	95%	90%	85%	100%

Key for colour coding:

- Low: Red
- Low/Medium: Red/Orange
- Medium: Orange
- Medium/High: Orange/Green
- High: Green

Key for abbreviations:

- B- Background information
- W – Waste Information
- 1 C– Public Health.
- 2 E– Environmental Control
- 3 R– Resource Mgmt.
- 4U- User inclusivity
- 4P – Provider inclusivity
- 5F – Financial sustainability
- 6N – National Framework
- 6L – Local institutions.

From table 3, the waste composition in each city is similar. The organic waste occupies around half of the total waste and the metal has the lowest disposal rate. It can be observed that the cities in China share a higher organic waste than the US, more than 60% of the municipal wastes are food or green waste. Zhengzhou has a very low paper disposal rate, 2.23% while the other three cities all have a similar rate around 20%. Beijing has a very low metal disposal rate, only 0.5%. In this set of data, the cities in the US have a lower organic composition rate than China.

In fact the most accepted concept of waste hierarchy is defined as 4R-reduce, reuse, recycle and recover. It has one more 'R' -recovery than the concept that the wasteaware indicator used. Recover means to covert waste into resources through thermal and biological means. It occurs after the other three concepts have been attempted. The results caused by this difference will be discussed in the discussion section. (Sadi, 2012)

New York and the Palm beach county can be seen as the high-income level and upper-middle income level region in the US. Same as Beijing and Zhengzhou, these two cities have the same situation in China. At first glance, with the help of the traffic light coding system, New York and the Palm beach have a better system performance than Beijing and Zhengzhou: they have more green shade than the other two cities. Among them, the Palm beach shows the best system performance. It has the highest recycling rate and all of the indicators have result defined as medium/high or high.

3.2Radar diagram

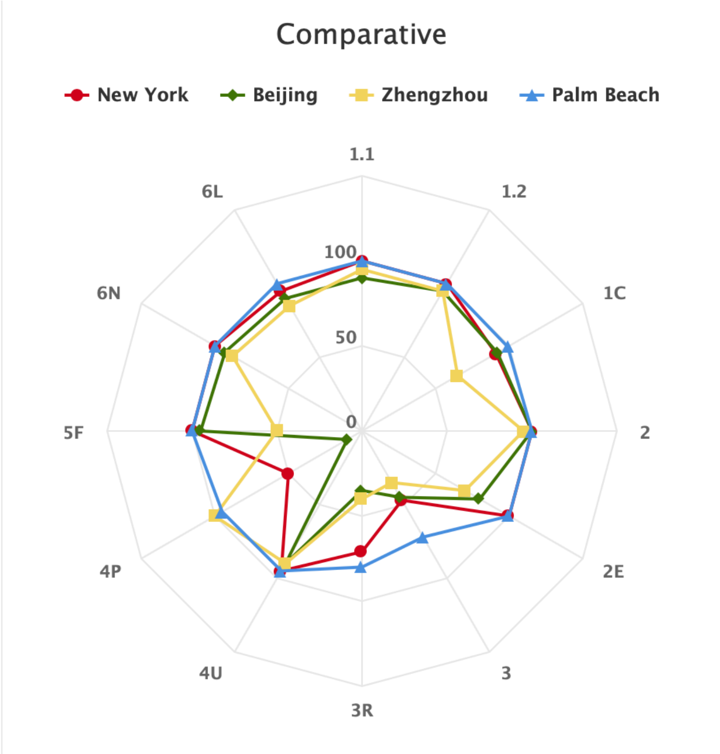

Figure 3 Radar diagram of four cities

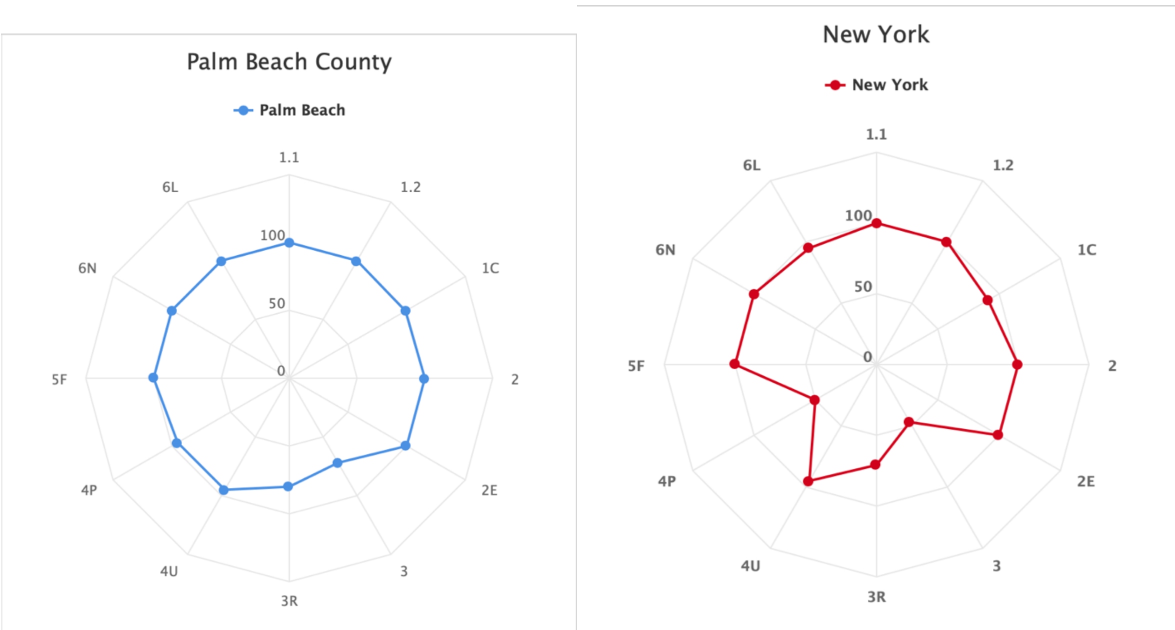

Figure 4 Radar diagram of Palm beach county and New York

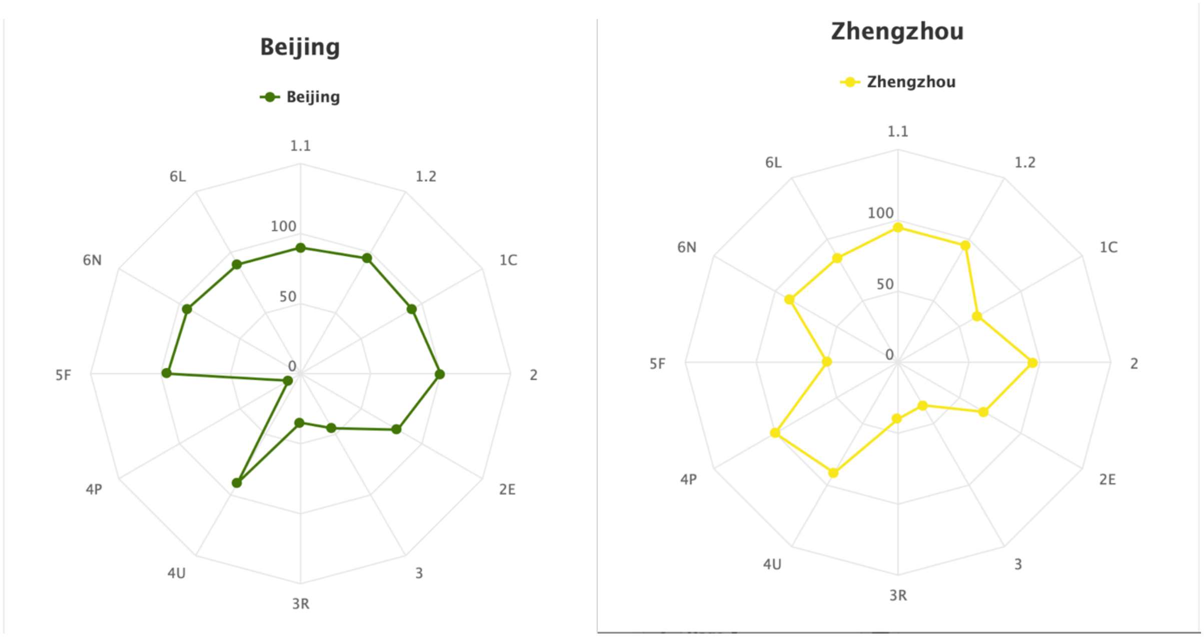

Figure 5 Radar diagram of Beijing and Zhengzhou

From the comparative radar diagram, one can see the evidence of the difference between systems in China and the US. In general, the system authorities have focused on the same field in the US and China. They put effort on public health-waste collection part. However, while all other three cities showed a high-quality performance on the public health driver, Zhengzhou only got 65% of the quality of waste collection service. All the reference cities have reached nearly full score on the controlled treatment and disposal indicators, but the cities in China are still encouraged to improve the quality of their environmental protection results. Interestingly, all the cities show a comparatively poor result on recycling, only 35% of the solid waste was recycled in Zhengzhou, while New York only got 47%. Palm Beach got the highest recycling rate, 72%, over the whole United State in 2017 due to its renewable energy facility. In general, in the recycling field, China still needs to learn from the US.

There is no clear trend in the performance against governance indicators. Except for Palm Beach, the remaining three cities still have room for improvement in the provider inclusivity area. It seems like all the cities have strong institutional frameworks and adequate services.

4.0 Discussion

4.1 Result analysis

As a lower-middle income level developing country, China shows higher collection coverage than it might have been expected. The reality is, the government has been put considerable efforts to increase the service coverage. In addition to the rural area, the great city area in China has a 100% service coverage rate. Households receive waste collection service every morning before 6 am. The solid waste is transported to the communal disposal site by public garbage tracks for centralized treatment. Same as New York, it has distributed thousands of brown or recycle bins to residences, office buildings, and other commercial establishments, some of the wastes are collected by private waste haulers, and others are by public institutions. (Sanitation, 2012)

The indicators of environment control show the percentage of total waste from the waste collection system that is destined for controlled disposal. Table 2 shows that except Zhengzhou, all the cities achieved 100% controlled disposal, however, even Zhengzhou which has the lowest capital income, still achieved 95% of the disposal rate. New York exported 80% of its solid waste to landfills to other states and 20% of the waste was converted to energy. (Galka, 2016) The New York government realized that relying on export leaves the city vulnerable in a long-term, one of the goals under PlaNYC is to divert 75% of the solid waste from the landfills by 2030. (CORPORATION, 2000)The Palm beach operated its new waste-to-energy plan in 2015 and the plan was estimated to reduce 90% of the waste to landfill.

Beijing and Zhengzhou are still on a traditional path. Beijing started converting its disposal method from landfill to thermal treatment from 2016 and Zhengzhou is still using landfill as the main method. Although the central government encourage provinces and cities to build new waste to energy plant, the local government still needs time to prepare and gradually moves away from landfill. All cities performed impressive in the environment control area, the success factor included strong determination and robust involvement of residence.

The average recycling rate across these four cities was lower than expected. Palm Beach has the highest rate, 72%, while the other three cities are all below 50%. High recycling rates generally require the processing of both recyclable and organic materials. In the US, the recyclable waste is separated by bins from the source, key boards, solid plastic, and paper is collected as the recycled material and send directly to the recycle center. (Sanitation, 2012)In China, even in Beijing, it is very unlikely to separate the wet waste from dry recyclables at sources. The waste sent to disposal sites is still a mixed type of waste.

However, although the US has a high score on resource value, it does not mean the US did a better job on post-recycled waste. The US has a higher recycle score but as New York, it delivered the remaining solid waste over long distant to other states and disposed the waste by landfill. The US now only has limit WTEs that still being operated. In China, the recycle rate may not be the highest, as they are still working on dividing the waste and recycles at the source, but it has a very high recover rate. In 2018, China has about 200 WTE plants. If the recovery rate was included as one indicator, the cities of China may obtain a better results. (Cheng, 2017)

The results from China in the table are derived only from the formal sector. However, in a lower-middle or low-income country, the recyclable materials are generally collected by itinerant waste buyers, which also called the informal sector. The material recovery in the palm beach and New York are mostly carried out by the formal sector, only a handful scavengers still exist. Unlike the United States, in China, regardless of the income level of the reference cities, scavengers, or other kinds of informal sectors, are an important component of the recycling system. In 2009, the scavengers collected more than 180 million tons of recyclable waste while the total recyclable waste was around 250 million tons. This has been shown to save the government budget of over hundreds million. After 2007, China has started to legitimize and facilitate the work of the informal sectors and transformed the informal sectors to private formal sectors. (C.Wilson, 2006) This transformation only standardized the waste recycling, but also stabilized the social order: as a low-income group, scavengers sometimes are considered to be one of the factors of social instability.

Accessing the solid waste management system in terms of governance factors requires professional judgment more than public data. In this research, as the indicator users noted, the information contributed to the result of governance indicators replied on the public news or government reports. The indicator users from Renmin University in Beijing rectified their results after discussing with the central committee of the environmental protection agency in China, therefore the authenticity of the data is still to be considered. As the results illustrate, the reference cities have great performances on 6N and 6L, hence the governance frameworks and fiscal sustainability in China and the US are both considered as strong and transparent. In Beijing and Zhengzhou, the financial budget relies entirely on property tax and municipal income tax, while the payment rate is still low. New York, Beijing, and Zhengzhou have a low provider inclusivity, but the causes are not the same. New York historically has a high commitment to institutional development, but the municipalities ignore the communication with communities and informal sectors. Except for Manhattan, the management of other informal sectors is immature. In Beijing and Zhengzhou, under the strong central planning and controlling, the participation of other providers were considered unnecessary.

4.2 Inaccurate data

The freshly collected data and its analysis has post some interesting results and also some remining challenges which could be improve in the future research study.
The data collected for this research from these four reference cities are unique and valuable. More than three professional indicator users were involved and shared their experiences of the cities' management systems. The results heavily relied on two things: one is the existing dataset and reports of the solid waste management system and the other is personal judgment. In both two countries the availability and the reliability of the data from the government website or database are poor, the data are out-of-date and incoherent. Some of the real data or personal judgment here do conceal considerable variations between the reality and publicity.

5.0 Conclusion

This study uses the 'wasteaware' indicator to compare the waste management performance of selected cities in the US and China. The rates of waste management disposition in the US has remained the same since the late 1990s. In 2011, 63.5% of the waste was landfilled, 29% of the waste was either recycled or composited and 7.6% was sent to waste to energy facilities. In China about 35% of the waste was combusted for energy and around 5%-10% was recycled. Around 60% of the waste was sent to landfills. (Shin, 2014)The indicator used in the analysis, integrates six dimensions for evaluating the systems with different backgrounds. Three dimensions are for quantitative analysis purposes, they focus on the physical drives of the systems: public health, environment disposal, and resource recovery. The other three components mainly focus on the governance aspect - inclusivity, financial sustainability, and sound institution and proactive policies. The comparative analysis looks first at waste generation rates and wastes composition rate. A radar diagram is prepared for each city as a powerful tool to evaluate the solid waste system in a comprehensive way. The traffic light coding system is applied to visualize the results. By using the indicator set, the reference cities in the US and China with significant differences in the income levels and policy backgrounds become comparable. The cities selected in China are capital and regional capital cities. They have had relatively sophisticated systems but are still seeking innovation, such as improving incineration and energy recovery processes to increase the thermal efficiency. The cities in the US heavily rely on the current systems, whereas innovation is rare.

The cities in China show a better performance than the cities in the US on recycling and disposal methods. The Chinese central government encourages local government to develop WTE plants as it is currently the best option to recover the waste after recycling. Reversely, the US government releases the right to state governments and let them recognize the best method for MSW disposal and the recycling and WTE developments are almost stagnated in recent decades. For the future improvement of systems, it is recommended that China should put more effort into the quality of the system performance and the US should adopt policies to encourage the waste to energy recovery.

Bibliography

Barron, J. (2018, Mar 22). *New York City's Population Hits a Record 8.6 Million*. Retrieved from New York Times: https://www.nytimes.com/2018/03/22/nyregion/new-york-city-population.html

Beede, D. N. (1995). THE ECONOMICS OF MUNICIPAL SOLID WASTE. *The World Bank Research Obseri er*, 113.

Bercegol, R. d. (2017). Waste Municipal Service and Informal Recycling Sector in Fast-Growing Asian Cities: Co-Existence, Opposition or Integration? *Resources*.

Berenyi, E. (2015). *PALM BEACH COUNTY, FLORIDA SOLID WASTE AUTHORITY WASTE TO ENERGY FACILITY* . Palm Beach: Governmental Advisory Associates, Inc.

C.Wilson, D. (2006). Role of informal sector recycling in waste management in developing countries. *Habitat International* , 797-808.

Cheng, Z. H. (2017). *Study of policies and regulations for waste management in China and potential for application in the U.S.* . New York: EARTH ENGINEERING CENTER COLUMBIA UNIVERSITY.

CORPORATION, S. A. (2000). *Characterization of New York City's Solid Waste Stream.* New York: New York City Department of Sanitation.

County, S. W. (2018). *FY 2018 Marketed Recyclables Report.* Palm Beach County : Solid Waste Authority of Palm Beach County .

County, S. W. (2018). *Renewable Energy Facility 2*. Retrieved from Solid Waste Authority of Palm Beach County: https://www.swa.org/Facilities/Facility/Details/Renewable-Energy-Facility-2-11

Galka, M. (2016, Oct 27). *What does New York do with all its trash? One city's waste – in numbers*. Retrieved from The Guardian: https://www.theguardian.com/cities/2016/oct/27/new-york-rubbish-all-that-trash-city-waste-in-numbers

protection, F. D. (2016). *Florida Municipal Solid Waste Collected and Recycled.* Retrieved from Florida Department of Environmental protection: https://floridadep.gov/sites/default/files/MSW-Composition_2016_1.pdf

Sadi, M. K. (2012). Reduce, Reuse, Recycle and Recovery in Sustainable Construction Waste Management. *Advanced Materials Research*, 446-449.

Sanitation, N. D. (2012). *New York City Commercial Solid Waste Study and Analysis.* New York: NYC Department of Sanitation.

Services, S. W. (2018). *Chapter 12: SOLID WASTE AND SANITATION SERVICES.* New York: Empire State Development.

Shin, D. (2014). *Generation and Disposition of Municipal Solid Waste! (MSW) in the United!States!–A!National!Survey!* New York: Columbia University Engineering Center.

Steven Cohen, Hayley Martinez. (2015). *Waste Management Practices in New York City, Hong Kong and Beijing.* New York.

Swisher, S. (2018, Dec 5). *Burning trash helps Palm Beach County near top of state's recycling list*. Retrieved from SunSentinel: https://www.sun-sentinel.com/local/palm-beach/fl-palm-recycling-rate-20160725-story.html

Sylvan, D. (2017). *Municipal Solid Waste in New York City: An Economic and Environmental Analysis of Disposal Options.* New York: New York League of Conservation Voters Education Fund.

Teotia, M. (2013). *MANAGING NEW YORK CITY MUNICIPAL SOLID WASTE - USING ANAEROBIC DIGESTION.* New Yrok: Pratt Institute, School of Architecture.

Wilson, D. (2014). 'Wasteaware' benchmark indicators for integrated sustainable waste management in cities. *Science Direct*, 329-346.

Wilson, D. C. (2012). Comparative analysis of solid waste management in 20 cities. *Waste Management & Research*, 237-254.

Zero Waste. (2018, Nov 12). Retrieved from One NYC: https://onenyc.cityofnewyork.us/goals/zero-waste/