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IMPROVING THE EFFECTIVENESS OF SOLID WASTE TREATMENT PLANTS VIA INTEGRATED SYSTEM APPROACH: A CASE STUDY ON MANISA

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ABSTRACT

This study investigates the ways of improving the effectiveness of the recently constructed waste treatment plants in Turkey. Many municipalities have made large public investments on modern solid waste treatment plants. These plants, designed to process hundred tons of waste per day, positively contribute to both the environment and the economy. However, the inefficiencies in other waste management activities (e.g. waste collection, transportation) could limit these plants' contributions, making it a priority to identify and remove the bottlenecks in the municipal solid waste system. This study examines the municipal solid waste system of Manisa, including the recently constructed Uzunburun Solid Waste Treatment Plant. Interviews with municipal public managers were conducted to shed light on bottlenecks that could limit the effectiveness of Uzunburun Plant. Then, integrated solid waste management framework was used to reveal possible ways to remove these bottlenecks. According to results, socio-cultural issues are of prime importance; however, the effects of actions addressing these issues are only observable in the long-term. Nevertheless, the results show that improvements can be made in a shorter-time period through some technical, legal, and institutional steps.

Keywords: waste treatment plants, municipal solid waste; recycling; theory of constraints; integrated solid waste management.

BÜTÜNLEŞİK SİSTEM YAKLAŞIMIYLA KATI ATIK İŞLEME TESİSLERİNİN ETKİNLİĞİNİN ARTTIRILMASI: MANİSA İLİ ÜZERİNE BİR ÇALIŞMA

ÖZ

Bu çalışma, ülkemizde yeni inşa edilen katı atık işleme tesislerinin etkinliğinin nasıl arttırılabileceğini araştırmaktadır. Son zamanlarda birçok belediye, modern katı atık işleme tesisleri için büyük kamu yatırımları yapmıştır. Günde yüzlerce ton atık işleyebilecek şekilde tasarlanan bu tesislerin hem çevreye hem de ekonomiye olumlu katkıları bulunmaktadır. Fakat diğer atık yönetimi faaliyetlerindeki (örn. atık toplama ve taşımadaki) verimsizlikler, bu tesislerin pozitif katkılarını sınırlayabilmektedir. Bu nedenle, inşa

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edilen bu atık işleme tesislerinden maksimum fayda elde edilebilmesi için belediye katı atık sistemindeki darboğazların tespit edilmesi ve giderilmesi gereklidir. Bu çalışma, Manisa'nın katı atık sistemini inceleyerek Manisa Büyükşehir Belediyesi tarafından yeni yapılan Uzunburun Katı Atık Bertaraf Tesisinin etkinliğinin nasıl arttırılabileceğini araştırmıştır. Bu çerçevede, belediye görevlileri ile görüşmeler yapılarak Uzunburun Katı Atık Bertaraf Tesisinin etkinliğini azaltan darboğazlara ışık tutulmuştur. Ardından, bu darboğazların giderilmesi için gerekli olan eylemler bütünleşik katı atık yönetimi modeli uygulanarak ortaya konmuştur. Sonuçlar, sosyo-ekonomik ve kültürel konuların öncelikli olduğunu gösterse de bu konularda yapılacak eylemlerin etkisinin ancak uzun zaman periyodunda görülmesinin mümkün olabileceğine işaret etmektedir. Bununla birlikte araştırma sonuçları, daha kısa sürede olumlu sonuçlar sağlayabilecek teknik, yasal ve kurumsal adımların da var olduğunu ortaya koymaktadır.

Anahtar Kelimeler: atık işleme tesisleri; belediye atıkları; geri dönüşüm; kısıtlar teorisi; bütünleşik katı atık yönetimi.

1. Introduction

Economic and population growth have increased the amount of municipal solid waste (MSW) generated in the metropolitan cities of Turkey (Turkish Statistical Institute, 2018). This situation may pose serious environmental and health risks (Hossain et al., 2011) unless municipalities are able to develop effective MSW management plans. Inappropriate MSW collection, transportation, and treatment methods can pollute natural resources (e.g. soil and water), which in turn, threaten human health (Tozlu et al., 2016). The need to develop an effective MSWM (municipal solid waste management) plan is necessary not only to eliminate these negative consequences, but also important in exploiting economic opportunities, such as producing energy from waste (Naroznova et al., 2016) and recovering economic value (Le Courtois, 2012) from recyclables.

Both national and local government authorities in Turkey have acknowledged the importance of MSWM. Waste reduction and recycling are major goals in the 2018-2022 strategic plan of Ministry of Environment and Urbanization (2017). This plan also offers financial support to municipalities from the central government budget for investments in waste treatment facilities. These strategic objectives and incentives appear to be encouraging municipalities to take important steps on waste management. Many city municipalities have recently invested significant amounts in large high-tech waste treatment plants (see Table 1). However, as Kanat (2010) cautions, these investments may not be effective if planning fails to consider all aspects of MSWM. For example, it is reported that the mechanical waste processing plants in India were shut down due to a lack of holistic planning (Shekdar, 2009).

Table 1. Municipal Investments on Waste Treatment Plants in Turkey

City	**Manisa**	**Balıkesir**	**Çorum**	**Edirne**
Cost	110 million TL	80 million TL	70 million TL	10 million TL
Area	22 hectare	8,9 hectare	67 hectare	16 hectare
Waste Processing	650 tons/day	500 tons/ day	200 tons/day	300 tons/day
Packaging Separation	650 tons/day	5.3 tons/day	60 tons/day	300 tons/day
Composting	85000 tons/year	-	5000 tons/year	5500 tons/year

Source: Hürriyet Newspaper (2017)

Modern and large waste treatment plants are necessary, but not solely sufficient, to achieve their construction purposes (i.e. turning waste into resources and eliminating negative environmental and health consequences). The theory of constraints (Goldratt, 1990) states that the performance level of the whole system is limited by the performance of its weakest component. Therefore, poor performance in other waste management activities (e.g. separation, collection, and transportation) will result in low return on investment from the recently constructed waste treatment plants. For this reason, the integrated waste management approach should be adopted, which simultaneously takes into account socio-cultural, technical, environmental, economic, institutional, and legal aspects of MSWM (Abdoli et al., 2016; Guerrero et al., 2013). This is the only way to identify bottlenecks at the steps of waste separation, generation, collection, and transportation, and allow sustainable solutions to be delivered, enabling the newly constructed waste treatment plants to reach their full potential.

This study aims to reveal the bottleneck points in the MSWM system that could limit the contributions of the newly constructed waste treatment plants in Turkey, and then highlights the actions that should be taken to yield a higher return from these plants. For this purpose, the integrated solid waste management model was used to examine the MSWM system in Manisa, where the Metropolitan Municipality has recently constructed Uzunburun Solid Waste Treatment Plant. The interviews were conducted with municipal public managers to shed light on the key bottlenecks blocking the effectiveness of Uzunburun Plant. The results make theoretical contribution by showing that although building a modern solid waste treatment plant is a significant step for an effective MSWM, it is not solely sufficient; other socio-economic, cultural, technical, legal and institutional factors should also complement the capabilities of these plants. The findings also provide guidance to public managers on the key points (bottlenecks) to be overcome in order to achieve a higher performance in the MSWM system.

The remainder of the paper is structured as follows. The definition, activities, and aspects of MSWM are reported in the next section. Next, the theory of constraints is depicted, and the purposes of study are stated. After the case selection and data collection processes are disclosed in the methodology part, the information on the case study area (Manisa) and Uzunburun Plant are provided. Finally, the findings are presented, and the paper is concluded with the discussion of these findings' theoretical and policy implications.

2. Municipal Solid Waste Management (MSWM)

2.1. Municipal Solid Waste (MSW)

Waste is defined as "any substance or object which the holder discards or intends or is required to discard." (EU Directive 2008/98/EC). According to Turkey's waste management regulation (2015), MSW mainly comprises household waste, but includes the commercial, industrial and institutional waste that are similar in content and form. This regulation lists forty subcategories under MSW, including recyclable items (e.g. paper, glass, plastics, metal, battery, textile and electronic products), mixed waste, garden & park waste, street residues, bazaar waste, the used cooking oil, the medicine waste, and some chemicals and hazardous materials (Waste Management Regulation, 2015). This regulation holds municipalities responsible for the management of MSW. By law, metropolitan municipalities are obliged to develop short and long-term MSWM plans that address environmental concerns, coordinate the waste management activities of district municipalities, construct waste treatment facilities, and support the educational programs and campaigns aiming to increase public awareness on waste management.

2.2 Integrated Solid Waste Management

MSWM involves the steps of waste generation, separation, collection, transportation, treatment, and disposal (Guerrero et al., 2013). These steps are quite complex because they are influenced by various socio-cultural, economic, environmental, technical, legal and institutional aspects. In addition, MSWM has many stakeholders, such as heads of households, waste pickers, recycling firms, district municipalities, and central government. The significance of these aspects and stakeholders may vary according to location, implying no one unique solution for the problems of MSWM (Contreas et al., 2010). For this reason, Integrated Solid Waste Management framework is proposed to consider all these elements in an integral way, in order to "promote the development of a waste management system that best suits the society, economy and environment in a particular location" (Klundert and Anschutz, 2001: p.11).

Figure 1 below shows the Integrated Solid Waste Management framework that illustrates the steps, aspects and stakeholders of the MSWM system.

Figure 1. Integrated Solid Waste Management Framework

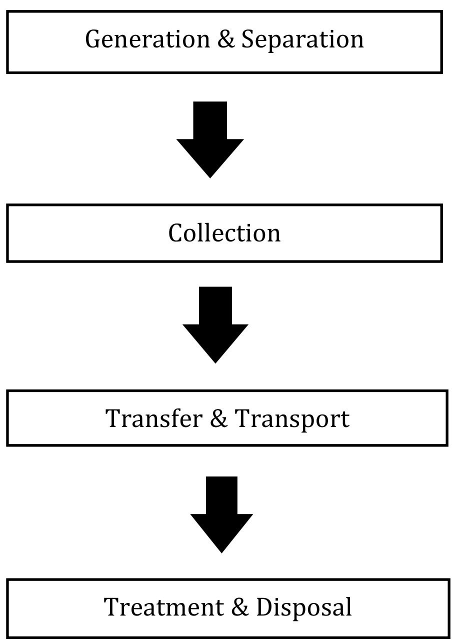
STAKEHOLDERS:

- Central Government
- Metropolitan Municipal
- District Municipalities
- Households
- Recycling Firms
- Itinerant Waste Buyers
- End-user Industries
- Municipal Workers
- Donor Agencies
- Waste Pickers

ASPECTS:

- Technical
- Environmental
- Financial / Economic
- Socio-cultural
- Institutional
- Policy / Legal / Political

STEPS



Source: (Klundert and Anschutz, 2001)

2.3 The Steps of MSWM

Waste Management Hierarchy (EU Directive 2008/98/EC) ranks the waste management activities from the most to the least preferable. On this hierarchy, reducing waste takes first position (i.e. the most recommended), because the MSW reduction saves the significant amount of pollution and cost incurred during waste collection, transportation, and disposal processes. However, since waste is inevitable, it is crucial to make accurate projections on the future amount and composition of MSW generated to develop an effective waste management planning. The studies list some factors that should be considered in these projections. Population is the leading determinant of the amount of waste generated (Contreas et al., 2010). Likewise, income level is positively related to the amount of waste generated (Oyekale, 2015; Korai et al., 2017), and affects the composition of waste. While the organic content in MSW is higher in less developed and developing countries, the ratio of recyclables is higher in developed countries (Storey et al., 2015; Ozcan et al., 2016). The amount of waste generated may also show seasonality, for example, the amount MSW may rise in winter due to daily heating (Turan et al., 2009). Alternatively, it may escalate in summer in touristic places (Kawai and Tasaki, 2016), or during day times due to daily labor migration.

The next step of MSWM is waste separation, mainly carried out by waste pickers, waste treatment plants, and households. Waste pickers earn money by separating waste and selling recyclables to recycling plants and/or industrial end-users (Matter et al., 2013). Although their activities may contribute to economy and environment, the informality of these activities poses many risks. Waste treatment plants also perform waste separation mechanically, after the mixed MSW is brought to these plants. However, the waste separation by households is highly encouraged, because separation at source minimizes the contamination of recyclables with organic waste, which enables recovering a higher economic value from recyclables (Chalmin and Gaillochet, 2009). Nevertheless, many factors affect the recycling (waste separation) behavior. First, the convenience plays a major role (Sidique et al., 2010; Miafodzyeva and Brandt, 2013). The physical constraints (e.g. high distance to recycling bins and lack of storage space for recyclables) negatively affect recycling behavior (Rousta et al., 2015; Zhang et al., 2016). Another important determinant of recycling behavior is social norms (Miliute-Plepiene et al., 2016; Sorkun, 2018a). People are more likely to separate their waste if peers and family approve of their act of recycling. Similarly, people tend to recycle more, when they perceive policy measures are effective (Wan et al., 2014). Education is also a strong predictor of recycling behavior (Bell et al., 2017; Meen-Chee and Narayanan, 2006), which increases the awareness of reasons for performing the recycling behavior. In addition, the studies reveal that some socio-demographic variables, such as age (Pakpour et al., 2014; Sidique et al., 2010), and income (Bell et al., 2017; Seacat and Boileau, 2018) are significant in explaining recycling behavior.

Waste collection and transportation are other important steps of the MSWM system, which comprise the significant portion of the MSWM cost (Yildiz et al., 2013; Demir et al., 2017). Thus, it is highly critical to design a collection system that meets the required service level in a cost-effective way. The two basic mixed waste collection systems are fixed station (drop-off collection), and community bin (street-side collection) (Shekdar, 2009). In the drop-off collection system, citizens deposit their waste in the designated places within a specified time interval. In the street-side collection system, the bins are installed along the streets, and emptied by municipal vehicles.

Each system (i.e. drop-off and street-side) has advantages and disadvantages. The drop-off collection system is less convenient for citizens due to the distance to waste bins, but decreases the waste transportation and handling costs of the municipality (Teixeira et al., 2014). In the street-side collection, the municipal waste collection and handling costs are higher; however, it is more convenient for citizens, because waste bins are closer. Other important considerations when choosing a collection system are the topography of region (the amount of distance that need to be travelled) (Qdais, 2007), population density (Kawai and Tasaki, 2016), road conditions (Henry et al., 2006), and traffic congestion (Ogwueleka, 2009). The densely populated regions enhance the efficiency of street-side collection system, while poor road conditions, traffic congestion, and difficult topographic conditions make the drop-off collection more favorable. Also, there may be an individual waste collection activity in the MSWM system (Kanat et al., 2006), which is usually performed by scavengers. It is more difficult to control scavengers, in case the street-side collection is performed due to the high concentration of bins. In this circumstance, the drop-off collection can be better choice to facilitate control; however, if the drop-off collection points are left unmonitored, it is much easier for scavengers to collect the significant amounts of recyclables at one time.

There are also other factors affecting the cost and service level of collection systems. The frequency of collection (Teixeira et al., 2014), the number of vehicles used (Greco et al., 2015), and the number of bins installed (Kumar et al., 2009) can improve service level, but incur additional collection cost. The equipment used also affect the efficiency of collection and transportation processes. High capacity bins and vehicles can decrease the total distance travelled (Kinobe et al., 2015), but may be impractical in particular locations due to their large size (Kum et al., 2005).

Although the use of technology requires high fixed cost, it can reduce collection costs while keeping the service level high. Standardized and mechanized equipment (bins and vehicles) increase the efficiency of the collection process. The use of route optimization significantly decreases time, distance and fuel consumption during waste collection and transportation (Demir et al., 2017). In addition, the use of smart bins, which show the level of waste, reduce transportation costs by only routing trucks to full bins (Folianto et al., 2015). Similarly, the use of compression trucks reduces the volume of waste, providing a transportation cost savings, especially for low-density waste (Kum et al., 2005).

Waste can be handled at transfer stations (which are used as transshipment points) before being shipped to disposal sites and waste treatment plants. At these stations, the waste is first sorted, and then loaded on to the large-capacity haulage vehicles in order to reduce transportation costs (Shekdar, 2009). The efficiency of these transfer stations depends on the effective coordination between metropolitan and district municipalities, because effective coordination in operational planning can increase the utilization of haulage vehicles (McKinnon and Edwards, 2010).

The final step of the MSWM system is waste treatment & disposal. Open dumping, previously a common practice in Turkey (Yay, 2015), has tremendous negative environmental and health impacts (Vujic et al., 2017). A recommended safer approach is sanitary landfilling which is “a scientific dumping of MSW using an engineering facility which requires detailed planning and specifications, careful construction and efficient operation” (Tozlu et al., 2016: p. 810). Despite its being safer, this method cannot capture the potential economic value of waste. Hence, as the EU Landfill Directive (1991/31/EC) requests that the municipalities should aim at decreasing the amount of waste directly landfilled without any pre-treatment.

Recycling, composting, and incineration are three common waste treatment alternatives that could generate an economic value (Banar et al., 2009). In the recycling process, the recyclable items in MSW are separated (from the non-recyclable ones), and then processed in the recycling plants. This enables obtaining basic raw materials for the production of new products (Sorkun and Onay, 2016). Incineration and composting techniques are applied for the non-recyclable materials in MSW. The former (incineration) produces energy by burning waste, and enables a decrease in the amount of waste landfilled; however, this process could cause air pollution (Abdoli et al., 2016). The latter (composting) is “a biological decomposition of biodegradable solid waste under predominantly aerobic conditions” (Tozlu et al., 2016: p. 810). The output obtained from this process could be used as an agricultural soil conditioner (Hargreaves et al., 2008). The choice between the use of composting and incineration techniques should depend on the particular waste composition (Yay, 2015). While the MSW including high-moisture content (organic materials) is more suitable for composting, the use of incineration is more appropriate where MSW is largely composed of combustible materials (Korai et al., 2017).

3. Theory of Constraints

Theory of Constraints (Goldratt, 1984) is a management philosophy that aims continuous improvement in the system performance through a holistic thinking approach. Although originally developed in manufacturing in order to increase the production output by eliminating the resource constraints (Şimşit et al., 2014), the theory is widely implemented in areas such as health (Sadat et al., 2013), customer service (Naor and Coman, 2017), and infant education (Trickey and Newburn, 2014). This popularity is mainly due to the ease with which the theory’s philosophy can be adapted to contexts. Accordingly, the phenomenon under investigation can be formulated as a system/process, with its various components. The analysis on these interdependent component enables the root problems to be identified and resolved (Şimşit et al., 2014).

Theory of Constraints defines the constraint (bottleneck) as “anything that limits a system from achieving higher performance versus its goal” (Goldratt, 1990, p. 4). According to this theory, every system has at least one constraint (bottleneck) that impedes the system performance. Any improvement in this constraint enhances the overall system performance. Thus, the primary focus should be to elevate the bottleneck process (constraint), because the improvement in non-bottleneck processes, rather than enhancing the system performance, simply creates idle time and queues in the system. The theory proposes five-step approach: (i) identify the system constraint, (ii) decide how to exploit the system constraint, (iii) subordinate everything else to the above decision, (iv) elevate the system constraint and (v) once a constraint is broken, identify the new constraint, and return to the first step (Goldratt, 1984).

4. The Purpose of Study

The MSW generated undergoes the steps of waste separation, collection, transportation, treatment, and disposal in the MSWM system. Hence, apart from minimizing the overall amount of waste generated, the goal of the MSWM system is to maximize the amount of waste recycled, converted into energy, composted, and safely disposed of. This amount can be increased only if the bottleneck processes are identified and elevated. Therefore, this study aims to accomplish the first two steps of the theory of constraints, which are identifying the system constrains, and then defining actions to exploit these constraints.

This study specifically seeks for the answers of following questions:

- What are the bottlenecks that constrain the effectiveness of Uzunburun Solid Waste Treatment Plant?
- Which aspects are these bottlenecks related to?
- What actions should be taken to elevate these constraints (i.e. remove bottlenecks)?

5. Methodology

This study employed a qualitative research method, because its research questions require in-depth inquiry. It is not possible to quantify the causal links in the MSWM system, due to the complexity and multi-dimensionality of the problem. Therefore, a case study, as a qualitative research method, was found appropriate to support the exploratory purposes of this study (Yin, 1994). In the case study method, the case should be carefully selected to serve the study's purpose. Flyvbjerg (2006) argues that when the purpose is to obtain the greatest amount of information on the phenomenon, random and representative sampling are inappropriate, because they provide an average information on the phenomenon; Flyvbjerg (2006) rather recommends a strategic case selection in these circumstances.

Following this suggestion, Manisa's MSWM system was considered as a suitable case study.

There are a number of reasons for selecting Manisa as the case of this study. To begin with, Manisa is one of few cities in Turkey, in which a solid waste treatment plant (Uzunburun) has recently been constructed. This makes relevant the research question of how it is possible to increase the effectiveness of the recently constructed waste treatment plants in the country. Next, Manisa has a large population, and is composed of 17 districts over a wide area, whose municipalities are governed by different political parties. All these qualities indicate that the MSWM system of Manisa is sufficiently complex, enabling the exploration of many improvement points (bottlenecks) related to various dimensions.

For data collection, it was considered that interviewing with the department managers of the Metropolitan Municipality could provide the richest source of information, because the laws hold Metropolitan Municipalities responsible for the management of the whole MSWM system. Thus, the department managers of Manisa Metropolitan Municipality were contacted, and Mr. Ertuğrul Yıldırım, the head of Environmental and Control Department in Manisa Metropolitan Municipality, agreed to give an interview.

Before the interview, to guide the conversation, questions were formulated based on information extracted from the previous studies, media news on Uzunburun Plant, and various public reports (e.g. strategic plans of Manisa Metropolitan Municipality and the Ministry of Environment and Urbanization). The semi-structured interview conducted with Mr. Yıldırım lasted around one hour. The notes were taken during interview, which was not tape-recorded to ensure a more comfortable and natural dialogue, potentially revealing a greater amount of information. After the interview, Mr. Yıldırım provided copies of some non-publicly available documents relevant to this study (the facility operation plan of Uzunburun Plant, the data on MSW composition, and the projections on MSW amount in Manisa). In the following weeks, the interview notes, documents, and media news were compared through data triangulation. The data were validated, and analyzed using the integrated waste management framework, in order to identify the bottleneck points in the MSWM system of Manisa.

6. The Case Study

6.1. Manisa

The region of Manisa is located in western Turkey, and covers an area of 13228.5 square kilometers. The city's population has been growing around by 10 percentage in each year, and reached 1,413,411 million in 2017 (Table 2).

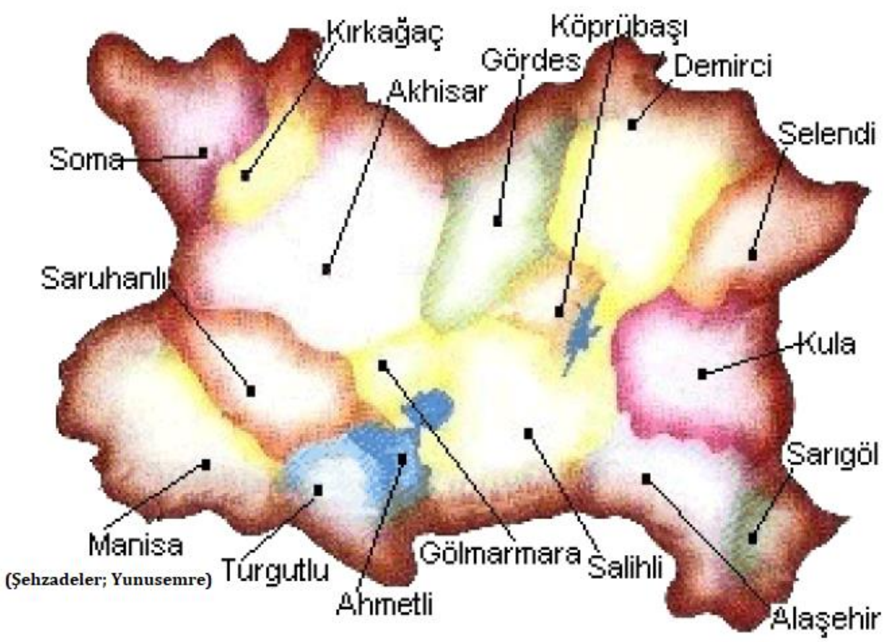
Table 2. The Population of Manisa between 2013 and 2017

Year	Population	Growth Rate
2013	1,359,463	9.8 %
2014	1,367,905	6.2 %
2015	1,380,366	9.1 %
2016	1,396,945	11.9 %
2017	1,413,041	11.5 %

Source: Tüik

Manisa is divided into 17 administrative districts as shown in Figure 2. The distance from each district to city center is provided in Table 3.

Figure 2. Map of Manisa



Source: ÇED Branch Directorate (2017)

Table 3. The Distance from City Center to Districts

District	Distance	District	Distance
Ahmetli	52 km	Kula	118 km
Akhisar	48 km	Salihli	71 km
Alaşehir	109 km	Sarıgöl	128 km
Demirci	158 km	Saruhanlı	17 km
Gölmaramara	66 km	Selendi	155 km
Gördes	107 km	Soma	87 km
Kırkağaç	74 km	Turgutlu	31 km
Köprübaşı	123 km		

Source: Manisa Metropolitan Municipality (2014)

Manisa Municipality was established almost 150 years ago in 1877 (Manisa Metropolitan Municipality, 2014). After the law enacted on 06/12/2012, Manisa Municipality gained the status of "Metropolitan Municipality". This law has brought two-tier municipal system, in which the district municipalities are responsible for providing municipal service to their districts, including the domestic waste collection, while the Metropolitan Municipality is responsible for coordinating the work of district municipalities and conducting projects for the entire city (e.g. the construction of waste treatment plant).

In 2018, the amount of daily waste generated per person in Manisa was projected to amount to 1.438 kg. This figure is projected to increase to 4.013 kilograms by 2047. Table 4 shows the projection on the amount of MSW generated in Manisa for the following thirty years.

Table 4. The 30-year Projection on the Amount of MSW Generated

Year	Daily waste per person	Population	Yearly total waste
2018	1.438 kg/person/day	1,433,588 persons	752,446 tons/year
2019	1.490 kg/person/day	1,454,517 persons	791,037 tons/year
2020	1.544	1,475,833	831,721

	kg/person/day	persons	tons/year
2021	1.600 kg/person/day	1,497,551 persons	874,570 tons/year
2022	1.658 kg/person/day	1,519,678 persons	919,663 tons/year
2023	1.718 kg/person/day	1,542,218 persons	967,078 tons/year
2024	1.780 kg/person/day	1,565,189 persons	1,016,903 tons/year
2025	1.844 kg/person/day	1,588,596 persons	1,069,222 tons/year
2026	1.910 kg/person/day	1,612,451 persons	1,124,119 tons/year
2027	1.979 kg/person/day	1,636,764 persons	1,182,290 tons/year
2028	2.050 kg/person/day	1,661,546 persons	1,243,251 tons/year
2029	2.124 kg/person/day	1,686,806 persons	1,307,713 tons/year
2030	2.200 kg/person/day	1,712,561 persons	1,375,187 tons/year
2031	2.279 kg/person/day	1,738,815 persons	1,446,408 tons/year
2032	2.361 kg/person/day	1,765,585 persons	1,521,519 tons/year
2033	2.446 kg/person/day	1,792,882 persons	1,600,668 tons/year
2034	2.534 kg/person/day	1,820,719 persons	1,684,000 tons/year

2035	2.625 kg/person/day	1,849,107 persons	1,771,674 tons/year
2036	2.720 kg/person/day	1,878,064 persons	1,864,541 tons/year
2037	2.818 kg/person/day	1,907,594 persons	1,962,095 tons/year
2038	2.919 kg/person/day	1,937,722 persons	2,064,517 tons/year
2039	3.024 kg/person/day	1,968,459 persons	2,172,708 tons/year
2040	3.133 kg/person/day	1,999,817 persons	2,286,881 tons/year
2041	3.246 kg/person/day	2,031,814 persons	2,407,272 tons/year
2042	3.363 kg/person/day	2,064,462 persons	2,534,116 tons/year
2043	3.484 kg/person/day	2,097,779 persons	2,667,661 tons/year
2044	3.609 kg/person/day	2,131,782 persons	2,808,163 tons/year
2045	3.739 kg/person/day	2,166,487 persons	2,956,681 tons/year
2046	3.874 kg/person/day	2,201,916 persons	3,113,533 tons/year
2047	4.013 kg/person/day	2,238,080 persons	3,278,217 tons/year

Source: Manisa Metropolitan Municipality

Below, Table 5 shows the composition of waste generated in Manisa.

Table 5. The Composition of MSW in Manisa

Type	**Ratio**
Recyclable waste	% 24.7
Biodegradable waste	% 46.2
Residual waste	% 14.4
Combustible waste	% 14.6
Hazardous and electronic waste	% 0.1

Source: Manisa Metropolitan Municipality

6.2. Uzunburun Solid Waste Treatment Plant

The uncontrolled dumping was the only waste disposal option in Manisa before Uzunburun Solid Waste Treatment Plant was constructed. In addition to the environmental and visual pollution caused by these uncontrolled zones, resulting fires and explosions threatened lives (İhlas News Agency, 2016). After Uzunburun Plant came into operation, work started to rehabilitate the uncontrolled dumping zones, in preparation for conversion into green fields (Manşet Newspaper, 2016).

Uzunburun Solid Waste Treatment Plant, which was opened in late 2017, has not only eliminated the above-mentioned problems, but also, due to its high technology infrastructure, enables the recovery of value from waste. The plant has four main sections, which are sanitary landfilling, mechanical biological separation, composting, and separation. According to the operation facility planning (Manisa Metropolitan Municipality, 2017), these facilities' yearly planned production quantities are respectively 2,950,978 tons/year, 150,000 tons/year, 70,000 tons/year, and 30,000 tons/year.

Below, Figure 3 shows the geographical position of Uzunburun Solid Waste Treatment Plant. The Uzunburun Plant is 13 kilometers from the city center.

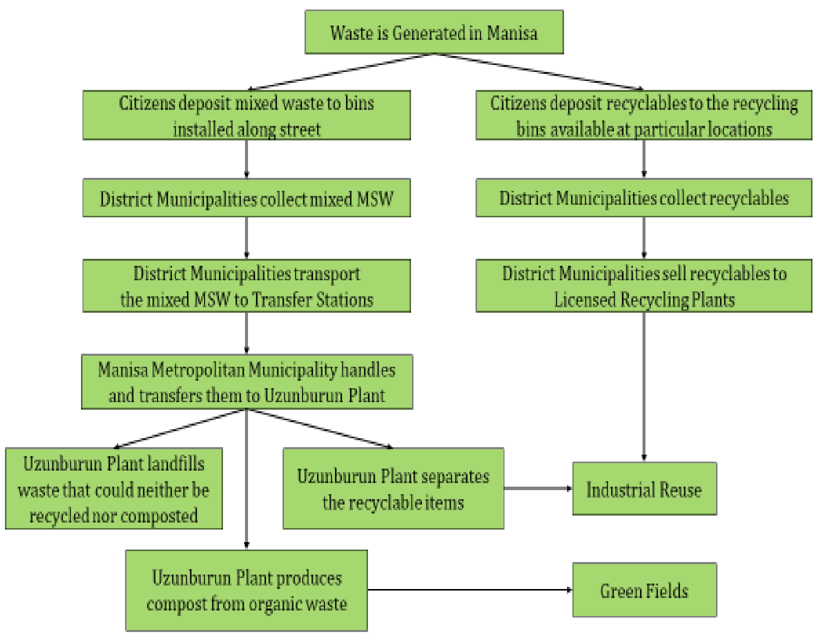
Figure 3. The Position of Uzunburun Solid Waste Treatment Plant

Although the plant is currently being operated by Manisa Geri Dönüşüm Enerji Üretim A.Ş., Manisa Metropolitan Municipality has a permanent technical team in the plant to audit the processes. The plant now serves five districts, and its current level of operational activity is able to process the 40-45% of the waste generated in Manisa. However, capacity expansions are still being made. The thermal facility, which will produce energy from waste, is nearing completion. Besides, the new plant expansion authorization has just been received, which will increase the annual amount of waste processed to 10,000,000 tons. After these expansions, Uzunburun Plant will serve all 17 districts of Manisa by 2050.

Uzunburun Solid Waste Treatment Plant is designed to process only MSW. Therefore, not all waste delivered to the plant are accepted, because some waste types may harm equipment or require a special treatment technique not available in the plant. For this reason, the incoming waste is accepted only if it conforms to the codes specified in the operational facility plan. The conforming waste is weighed, recorded, and then unloaded on an impervious ground. After the dissembler machine removes the MSW from their bags, it is carried to drum screen by conveyors. Here, the waste is routed in the plant according to size. Pieces smaller than 80 mm are directed to magnetic separator and then dispatched to the compost area for the fermentation process. This forty-day-process yields the compost that can be used in green fields. Waste between 80 and 300 mm passes through six optic separators. At this phase, the recyclables such as plastics, metals, nylons, paper, and carton are separated and sorted with respect to type before being pressed and shipped to licensed recycling firms. The non-recyclable waste obtained at this phase is directed to the compost area. The waste larger than the 300 mm is separated into light and heavy materials using a pneumatic separator. Light materials can be used as fuel. Finally, sanitary landfilling is used for any remaining inorganic material that cannot be recycled (e.g. clay, geotextile).

Below, Figure 4 illustrates the flow of waste from generation to disposal in Manisa.

Figure 4. The Flow of Waste in Manisa



7. Findings

The analysis results show the existence of various technical, socio-cultural, economic, legal, and institutional constraints (bottlenecks) that impede the performance of MSWM system in Manisa. Table 6 illustrates the MSWM step and aspect corresponding to each constraint identified.

Table 6. The Existing Constraints in the MSWM system of Manisa

Step	**Aspect**	**Constraint**
Generation	Economic	The increasing income levels
	Socio-cultural	Consumption culture
Separation	Socio-cultural	Lack of social influence
	Socio-cultural	Lack of environmental awareness
	Economic	Lack of storage space
	Economic	Long distance to recycling bins
Collection	Financial	Non use of technology in vehicle routing
Transportation	Technical	Lack of transfer stations
	Legal	The location of waste plants (ÇED)
Treatment	Technical	Oversize materials and ash residue
	Political	The manipulation in MSW codes
	Institutional	Lack of engineers in district municipalities

The findings reveal that the constraints listed in the treatment step (Table 6) directly affect the efficiency of processes implemented in Uzunburun Plant, while those at the steps of generation, separation, collection, and transportation only indirectly decrease efficiency.

The results highlight three constraints at the step of waste treatment, which directly decrease the operational performances of processes implemented in Uzunburun Solid Waste Treatment Plant. These are problems with size of waste, non-conforming waste, and lack of technical knowledge. First, oversize materials and ash residues create technical problems. Some materials in MSW, such as curbstones and electronic devices, are too large to be processed by the plant's machines, while very fine ash residues harm the mechanical equipment. These problems sometimes halt the processes in the plant. For this reason, Manisa Metropolitan Municipality promotes the use of ash containers through leaflets, billboard videos, and seminars. The second constraint identified at the step of waste treatment is the delivery of waste not conforming to the MSW codes of Uzunburun Plant. District municipalities may send these types of waste (e.g. medical, hazardous, and industrial waste) because refusing to deal with such waste may affect their standing among influential industrial entities in their districts. The third constraint found at the step of waste treatment is that district municipalities lack engineers with sufficient technical knowledge. This makes difficult to specify the exact technical requirements (i.e. regarding oversize materials) and goals of the plant, which district municipalities should consider during waste collection process.

Inefficient MSW supply is another constraint that impedes the effectiveness of Uzunburun Solid Waste Treatment Plant. MSW, the main input of Uzunburun Plant, should be provided not only constantly but also economically. Currently, Uzunburun Plant can serve only five of seventeen districts in Manisa. This is mainly because of the lack of transfer stations in other districts. As stated in the previous section, the significant distances between the plant and some districts in Manisa prevent the economic transportation of MSW. For this reason, Manisa Metropolitan Municipality is constructing more transfer stations, most of which are still under construction.

The location of Uzunburun Plant also reduces the efficiency of transportation process. It is a legal requirement to get a positive environmental impact assessment certification (ÇED) for the construction of waste treatment facilities. By law, the decision-making committee involves residents (citizens), who are often reluctant to allow waste plants to be located close to residential areas due to general conviction that the plant operations have local environmental and health impacts. However, the plants located far from residential areas make the transportation of MSW costly and less reliable, as in the case of the Uzunburun Plant.

The failure to use no technology to optimize the routing of vehicles is a significant constraint in the waste collection stage. District municipalities in Manisa could not find affordable technologies to enable vehicle route optimization, even though the efficient use of these technologies could more than offset their purchasing cost in the long-term. The elevation of this constraint could provide a reliable delivery to transfer stations, which in turn contributes to the constant and sufficient MSW supply to Uzunburun Plant.

Constraints at the phases of waste generation and separation limit the performance of MSWM system. The increasing income levels and the prevailing consumption culture are escalating the amount of

MSW. Unless measures are taken to reverse this trend, the capacity of Uzunburun Plant, despite its expansion plans, will inevitably be insufficient. At very least, the waste separation at source should be promoted to decrease the burden on Uzunburun Plant. However, the habit of separating waste is not common in Manisa. There is also a lack of social influence; that is, recycling is not yet a socially encouraged activity. In addition, economic and financial circumstances cause physical constraints (high distance to recycling bins and lack of storage space), making the waste separation activity inconvenient. District municipalities are not financially equipped to provide a sufficient number of recycling bins to enable easy access. Besides, insufficient space in houses hinders separation of recyclables at home.

8. Conclusions

Fortunately, an increasing number of municipalities in Turkey have installed solid waste treatment plants to reach their sustainability goals. This situation implies a rise in the level of awareness on waste management in Turkey. While appreciating the municipalities' investments on solid waste treatment plants, this study cautions that the existence of these plants is not sufficient. All supporting waste management aspects should be sufficiently effective to allow the full benefits of waste treatment plants. Therefore, this study argues that an integrated system approach should be adopted to ensure the harmony between different waste management stages, as with other public services, such as education and health. Building modern university campuses and hospitals are the necessary preconditions to providing a high level of education and health services; however, these are worthless without high quality scholars and doctors.

This study makes its contribution by revealing the bottlenecks that impede the effectiveness of the newly constructed solid waste treatment plants in Turkey. For this purpose, the analysis focused on the MSWM system of Manisa, with the recently constructed Uzunburun Solid Waste Treatment Plant. The results highlight many technical, legal, socio-cultural, financial and institutional improvement points (bottlenecks).

The results show that each of the three bottlenecks identified at the step of waste treatment is related to a different aspect: technical, political, and institutional. However, their cause seems to arise from the same problem, a lack of goal alignment between stakeholders (i.e. metropolitan municipality and district municipalities). By law, the primary duty of district municipalities is to collect waste and maintain cleanliness. Since waste treatment is not their primary responsibility, it would be overoptimistic to expect district municipalities to pay a high level of attention to issues, such as identifying oversize materials and separating ash residues. Likewise, it is not the primary concern of district municipalities to employ engineers for providing a better technical communication with other stakeholders. The case study shows that district municipalities may even sometimes bring the non-appropriate waste category to the waste plant, in the interests of local industrial entities, because their main goal is to provide a high level of service exclusively to entities in their districts. All these underline the need for a centralized waste management over an entire city. In other words, all stages (waste separation, collection, transportation, and treatment) should be carried out by a single entity, whether a Metropolitan Municipality or a recycling firm. Only in this way can an integrated waste management approach be adopted, and the respective bottlenecks can be eliminated through a goal alignment.

As the bottlenecks at the step of waste transportation are analyzed, attention is drawn to the escalating transportation costs due to the locational problems of solid waste treatment plants. Some legal changes, shown as the main drivers of sustainable acts (Sorkun, 2018b), are needed to eliminate this problem. Considering that the newly constructed waste treatment plants are technologically capable of meeting strict safety requirements (i.e. their operations do not have harmful effects on environment and health), there is justification for greater flexibility in the legal requirements on these plants' locations, which will result in higher operational performance. Currently, the construction of a solid waste treatment plant requires "a positive environmental impact assessment certification". However, the prejudices on these plants' negative environmental effects on residential areas cause the decision committees to approve the locations only if remote from residential areas. As Mr. Ertuğrul Yıldırım suggests in the interview, a possible solution is a legal change that requires only the certificate stating "no need for receiving a positive environmental impact assessment". This legal change could enable the construction of new waste treatment facilities closer to residential areas that lower transportation costs and ensure a continuous supply of waste to the plant. If not possible to make such legal change, the locations of transfer stations used to consolidate MSW should be carefully chosen to provide economic and reliable access to the plant.

Despite the newly constructed solid waste treatment plants, the results reveal the difficulty of keeping the waste processing capacity sufficient over time due to the tremendous increase in waste generation. Thus, the efforts should also be made to provide a reduction in waste generation and an increase in the waste separation behavior. Both require creating an awareness in younger generations through educational activities such as those conducted by Manisa Metropolitan Municipality (e.g. organizing competitions, giving seminars in primary schools). The increase in waste separation behavior also requires providing a minimum level of convenience to people, such as minimizing the distance to recycling bins, and the frequent door-to-door collections of recyclables.

This study highlights the fact that quality and throughput of system output mainly depend on two factors: system inputs and conversion process. The newly constructed solid waste treatment plants ensure the successful conversion of inputs (MSW) into outputs (energy, recyclables). However, it is also critical to feed these plants with input (MSW) delivered at the appropriate time, and in the appropriate quantity and form. Here, the pre-treatment processes (i.e. generation, separation, collection, and transportation) play a major role. This study has examined these processes and identified many improvement points that could help public managers formulating relevant policies for an enhanced MSWM system.

This study has a number of limitations that could guide future research. First, the findings are obtained by only examining one case, Manisa. In order to validate and generalize the findings, future research could also examine other cities, for example Edirne and Balıkesir, which also have recently constructed solid waste treatment plants. Moreover, this study reveals many bottleneck points, however due to its qualitative method, is unable to show which of these actually impact the performance of MSWM system significantly. Future research could use quantitative techniques to quantify the impacts of improvement points identified in this study. This could provide more precise guidance to public managers on the precise areas to target in the improvement of the MSWM system.

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