The Technological Challenges Towards Sustainable Municipal Solid Waste Management System Based on a Service Sustainability Perspective: A Case Study of Bangkok, Thailand

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***Abstract*—Consumerism and waste generation should be managed to work concurrently. The more consumerism uses up resources, the more waste is generated. Municipal Solid Waste (MSW) is clearly witnessed as one of the most severe environmental problems, but waste management technology advancement is halting. Waste Management services have failed to respond to ever growing amount of waste. If technology remains unchanged, we need more resources to manage the waste generated. This study concentrates on technological challenges of MSW management (MSWM) system and identifies success factors to overcome technological gaps, which can be occurred along management chain. Thus, technologies used in waste management system will be studied by questionnaire survey and direct interview together with secondary data analysis. Public participation is an essential key for successful MSWM system because residents are main generators. As technology is a key factor for MSWM, a basic public service should be provided to resident to make system effectively run itself and eventually contribute to better system for quality of life. To identify the success factors for a sustainable MSWM transition, this study will trigger and incorporate human aspect on technology for MSWM by studying service providers and service recipients' experience and attitudes on MSWM.**

I. INTRODUCTION

Overwhelmed waste generated is consequent side effect of growing consumption and production. Concurrently with more demands of goods and services to serve human needs, the more amount of waste is disposed of to the environment. This tends to increase with the economic development and rapid urbanization of the society [1 – 2]. Focusing on municipal solid waste (MSW), the amount of MSW produced has been rapidly increasing in the last decades [3]. The world generates approximately 1.3 billion tons of MSW a year. It is expected to be 2.2 billion tons in 2025 [4]. With the conservative forecast, urban areas of Asia would generate 1.8 million tons a day of MSW in 2025 [5]. The increasing generation of MSW is one of the serious problems particularly for urban areas especially in developing countries with depleting landfill spaces and limited capacities [6]. This increasing waste generated amount together with more awareness on human health, environmental impacts, social problems, and depleted natural resources have yearned for strategies and techniques to reduce amount of waste and sustainably alleviate MSW related problems for more effective waste management systems [7-8].

The provision of adequate sanitation services is crucial. Proper disposal of all waste is vital to mitigate health risks [9]. Waste management is a basic public service should be effectively provided to residents that will eventually make the system run itself productively and ultimately contribute to better system to reach quality of life. Municipal solid waste management (MSWM) is an increasingly burdensome challenge for related stakeholders especially residents and responsible authorities in many cities around the world [10-12]. Dealing with ineffective waste management systems, several options associated to many methods, for example, supply chain management, life cycle analysis, and integrated waste management system have been mapped in waste management strategic policies [13-19]. Despite that cause, there still be necessitated demand for an improved level of waste management service having been provided inadequately from responsible authorities.

Thus, MSW is urgently in need of effective solid waste management strategies. The effective MSWM strategies should be applied to manage all types of waste and applicable not only to the national level where guidelines, targets, and strategic action plans are set, but also at the local level where waste management actually takes place [20-22]. Difficulties in providing waste management service corresponding to demands are typically due to institutional, technical and financial constraints at national and local government levels, as well as in the private sector [23]. Particularly, management systems and techniques have been developed to decrease the environmental burden of waste production. Among all the developed techniques, we must provide a sustainable waste management system effectively supporting management services to the residents. It is essential to apply appropriate technologies to waste management systems. This paper aims to identify technological challenges of MSWM system and finds success factors to overcome technological gaps in an urban city of a developing country, Bangkok, Thailand. The technological gaps which will be occurring along management processes and are one of the main reasons that misleads performance of waste management system. To identify the success factors for a sustainable MSWM technology transition, this research study will trigger and incorporate human aspect on technology for MSWM by studying service providers and service recipients' experience and attitudes on MSWM.

II. THAILAND WASTE MANAGEMENT SCENARIO

A. Overview

Waste situation has reached its threshold level, especially in developing countries such as countries in Asia. According to the U.S. Environmental Protection Agency, MSW generation has increased by 2.6 times from 1960 to the present [21]. This amount of new waste generated is an additional to a huge amount of waste that has been left in many landfills. As stated earlier, MSW management is a public service [24]. Effective waste management service should be efficiently provided to all people to live in a good environment, good hygiene, and good standard of life. The accomplishment of the waste management system highly depends on the effectiveness of MSWM system. Unfortunately, MSWM system in many developing countries is relatively ineffective despite a relatively high proportion of budget spent. This leads to an incomplete historical long-term planning which impacts the effectiveness of waste management system [25].

Bangkok, the capital and the fastest growing city in Thailand, has continuously witnessed accumulating MSW management problems. The amount of generated solid waste mainly depends on population, economic growth, and the efficiency of the reuse and recycling system. Both the growth of economic development and the population increasing sharply from 48 million in 1982 to 65 million in 2012 really enlarge MSW generation in Thailand. As of December 2012, population in Bangkok is 5,673,560, which is about 9% of the total population in Thailand [26]. As a result, there are more than 300,000 tons of MSW generated monthly in Bangkok [27].

The quality of the environment is therefore a matter of growing concern. The Bangkok Metropolitan Administration (BMA), who is responsible for the city management and the well-being of Bangkok residents, has realized that the problem of waste is increasing. Like other countries, BMA seeks to avoid environmental pollution by encompassing various strategies, such as the 3Rs, efficient waste collection and disposal system campaigns, and effective participation of government, public, and private sectors. Sine 2004 community based solid waste management (CBM) has been applied as a concept of solid waste management aimed for waste reduction at sources and mutual benefit creation between the communities and BMA [28-30]. The policies, strategies, or plans have been successfully implemented in some countries. In addition to needs of an integrated waste management system that suits the characteristics of the City, solid waste problems in Bangkok are still in need for further attention through the involvement of related parties, a well-designed long-term master plan, and most importantly applications of technologies to each management process.

B. Municipal solid waste management situation

Waste is defined as any residual material from industrial and human activities that has no residual value [31]. According to the Thailand Public Health Act 1992, MSW includes waste from community activities generated from residential households, commercial and business establishments, fresh markets, institutional facilities, and construction and demolition activities, excluding industrial waste. There are four types of MSW in Bangkok that are organic waste, general waste, recyclable waste, and hazardous waste [28-30, 32]. Under the BMA, the Department of Public Cleansing (DPC), together with the fifty Bangkok City districts, is responsible for cleansing the City and reports the amount of waste collected from all districts. MSW is collected from the receptacles in front of houses, buildings, or designated locations on the specific dates and times. The collected MSWwaste is first transferred to three locations, namely On Nut, Nong Khaem, and Sai Mai. Then it is transported to two landfill sites in two nearby provinces, Nakonpathom and Chachoengsao. Hazardous waste from three stations is managed and transferred to an incineration plant in Samutprakarn province by a contractor [28-29, 32]. In 2013 the BMA collected on an average of 8,766 tons per day of MSW, which represent 21% of the country waste amount. About 90% of the collected waste is managed by disposing in sanitary landfills and 10% of the rest treated by being composted at On Nut waste disposal center [32-34].

Waste composition is different based on economic growth, people behavior, and activities. However MSW in Bangkok is homogenous in every district. The 54.84% of waste can be composted (food waste, woods and leaves), 10.64% can be recycled (recyclable paper, plastic, foam, glass, and metal), and 34.49% to be landfilled (non-recyclable paper and plastic, rubber and leather, textiles and garments, and stones and bones), with an average moisture content of 55.6%, density of 0.38 kg./liter, and heat value of 1,373.25 Kcal/Kg [32]. As MSW is one of the five critical issues of the City, the BMA's targets aim at having sustainable solid waste management to reduce environmental impacts and global warming in Bangkok. To achieve the targets, the BMA organizes projects, for example "solid waste management at sources" to promote public participation in waste reduction and increase yields of recyclable material from being contaminated.

Currently there are two main concerns. First, diminishing landfill volume, the increasing generation of MSW is a major problem in Bangkok as there are signs of insufficient landfill capacities. The BMA has been unable to find a new land as a new landfill site. In the City environmental master plan, there will be an incinerator with a pilot capacity of 300 ton per day. However, it has been postponed for a few years and has expected to start operation within five years. Second, it affects community and society, and the most important, the environment. According to the study of DoE and Thailand Environment Institute (TEI), dirtiness and untidy environment of the City are main social problems. Environmental pollutions are bad smells from landfills; groundwater, surface water, and soil contamination from leachate; spreading of diseases by different vectors; uncontrolled release of methane and other GHGs from anaerobic decomposition and fermentation of waste in landfills; and burning and explosion from landfills [32, 35-36].

According to the study of Garrod and Willis, there are 6 functional elements grouped by activities associated with MSW management, including waste generation, waste storage, waste collection, waste transfer and collection, waste processing, and waste disposal [36]. In order to have an effective and sustainable MSW management system, it is important that all applied and social studies are linked with a good management plan that involves all sectors from all levels [37].

Waste collection policy states that all locations are to service to make the City clean. Each district office gets support from the Department of Environment (DoE) in terms of machines, waste collection trucks, boats, and waste bins. The district offices collect waste based on the scheduled date, time, and location given by the BMA; and ensure of cleanliness that will be no leftover waste. In terms of collection trucks, there are currently 2,031 trucks in total, which 1447 are rented trucks and 554 are BMA's trucks. The DoE rent the trucks and allocate them to districts for waste collection. Figure 1 shows numbers of trucks based on different types [27].

C. Municipal solid waste management resources and technologies

Global Positioning System (GPS) technology is applied to manage and control waste collection. To deal with the growth of the population and the consequence increased waste, to increase the efficiency of waste management service and to ensure its cleanliness, the BMA set the budget of 5 billion baht for collection and disposal of waste in 2015. Collected waste is weighed at the waste disposal stations. The weight data is recorded and transferred to the central database of the DoE on real time basis. This allows all responsible persons access to the information anytime through each district's computer system. The DoE employs 1,317 employees to work with solid, hazardous, and nightsoil management and 394 employees for solid waste disposal [27-29]. The efficiency of waste management system service depends on many factors at all waste management processes for examples, collection routes, amount of waste, distance, traffic, collection methods, number of trips, weight per trip, and treatment methods. As mentioned earlier, MSW is clearly witnessed as one of the most severe environmental problems. Anyway, waste management technology advancement is halting. Although the BMA has performed well in Bangkok, there are some areas that waste Management services have failed to respond to growing amount of waste. If technology remains unchanged, more resources to manage waste generated are needed. Going towards sustainable and effective waste management system, it is important to take into account of the importance of technology.

Although there are clear policies set to ensure effectiveness of waste management system, there are some problems in the current operation, for example, trucks are ineffectively used or used inappropriately and low working performance of some staff. It results in ineffective waste management, leftover waste, waste of resources and additional expenses absorbed by the BMA. As a consequence, the BMA decides to increase the use of current technologies and enhance their performance in order to cope with the problems. For example, the installation of GPS and Fuel Level Device (FLD) are applied to improve the fit of collection routes and number of trips in each area. These technologies help the BMA to optimize the use of trucks, control fuel usage, save costs, control speed, and provide accurate information used for seeing the system performance, mitigating problems, and providing more effective waste management service finally increasing Bangkok residents' confidence on the provided service.

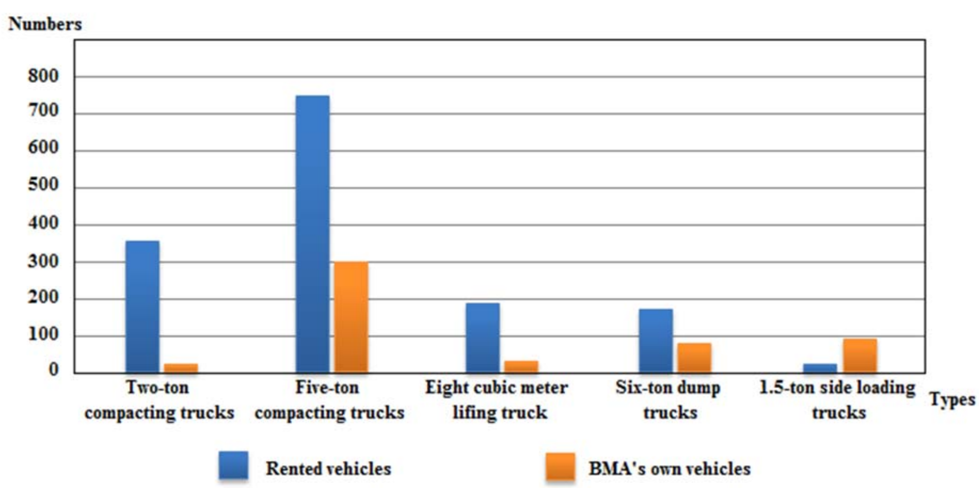

Fig.1: Type of waste collection trucks [27]

It is clearly seen that the BMA has applied some technologies to waste management system. However, having a sustainable system that meets the needs of service providers and service recipients, there are technological challenges that the BMA has to consider. Technology brings an array of benefits to environmental and public health. Understanding technological change and applying appropriate technologies provide a fundamental basis for sustainability transitions [38-39, 63-64]. This paper aims to identify those challenges and point out key success factors leading the system to a sustainable technology transitions.

III. RESEARCH METHODS

All findings that will be soon presented in this paper were obtained from primary and secondary data analyses. Their analyses were done qualitatively and quantitatively which are explained in subsections below.

A. Data collection procedure

To acquire primary data, it was done by launching 422 questionnaire surveys conducted between December 2013 and January 2014. This sample size was calculated with a 95% confidence level based on Yamane's simplified formula [40-41].

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

The population frame for the survey was people in Jatujak district, Bangkok, from communities, department stores, schools, universities, companies, temples, markets, hospitals and hotels [28-29].

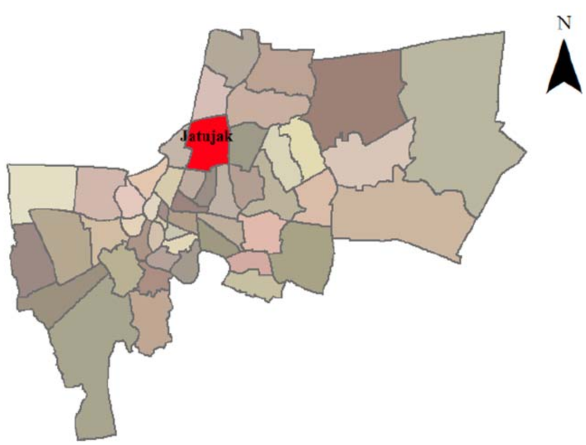

Fig2: Jatujak District, Bangkok, Thailand [42]

Sampling method of this survey was random sampling method. The surveys were conducted by interviewing respondents directly, so there was no missing questionnaire.

Moreover, there were nine expert semi-structured interviews from various key stakeholders from government institutions, educational institutions, NGOs, and from community based management projects. During the interviews, interviewees were able to freely express their opinion on MSWM regime in general as well as any other MSW related topics. The in-depth interviews were conducted in order to obtain practically technological information, implications, and comprehensive thinking from people involving in waste management system. The collected data were successively transcribed and incorporated into other analyses.

On the basis of accuracy and consistency, secondary data analysis was done by literature and documents reviews from reliable sources both from published journals, reviews, or government databases. The collected data were subsequently used to validate and complement to the paper, providing valuable insights into the research study.

B. Measurements

The questionnaire consists of 77 queries from 21 questions. Out of these questions, there are 4 parts in total, which are general information of respondents. This part inquires demographic information, household size, and monthly income of respondents. The second part is MSW sorting and disposal behavior of respondents. This part asks about waste management behavior, waste generation amount, and waste disposal frequency. The third part is MSW situation and attitudes of respondents. This part aims to get information about current MSWM performance and how MSW service should be in respondents' point of view. The fourth part is technological challenges and attitudes of respondents. This part aims to see what technologies are currently applied to MSWM, what potential technologies for MSWM are, and how technologies can benefit MSWM system. To be more specifically on technological challenges on MSWM, respondents were asked to answer what influential technologies are for each process of MSWM namely waste collection, waste transportation, and waste treatment based on their experience and knowledge.

Experts were asked questions about current MSWM service in Thailand, especially in Bangkok; what influential factors that have impacts on the effectiveness of MSWM. Questions about level of technology applied to management service and their opinions on performance or utilization of the technology were given. Based on the experts' knowledge and experience, the interview led to questions related to suitable technologies to be applied to each waste management process and how likely the MSWM system runs successfully with these technologies. The last point given to the interviewees was about sustainable waste management and service. The questions were to ask why MSWM in Bangkok should have a sustainable MSWM system, what needed essential factors are, and who should be involved in the system. Moreover, achieving a sustainable waste management service, questions like who should be involved in MSWM process, roles of stakeholders, how it would be, and likely it to be successfully happened in Bangkok were asked.

C. Data analysis

The data were then analyzed by using SPSS Statistics version 17 computer program, Descriptive statistics were used to organize and present the respondents' demographic profile. Since the objectives of this paper are to find success technological factors that have positive impacts to the effectiveness of waste management system based on human aspects; Pearson's chi-square model fit tests were done to screen variables, which are technologies needed for each process of MSWM. To do a preliminary screening of influential factors, the tests were done by performing two-by-two tests of association between the current use of technology in MSWM and specific technologies used in each MSWM process. With the usable 422 samples, to ensure that the data are analyzed effectively, some questionnaire items were eliminated by employing an explorative factor analysis (Principal Factor Analysis - Promax Kaiser Normalization Rotation method) to determine the technological challenges on MSWM in Bangkok, based on human aspects [69]. In terms of technology influence on MSWM, there are three analyzed groups of factors which are technology for cost reduction, technology for social improvement, and technology for sustainability. A Likert type five-point scale was used for the answers.

Besides, using the program, insightful data were gathered from respondents' knowledge and ideas on their aspects on the current MSWM and the importance of technology for the management system. In addition, a relatively openly designed semi-structured interview is more likely to more information from interviewees. In this study, qualitative data were analyzed by using documentation, conceptualization, and examining relationships techniques. Besides observing during the interviews, in the meantime, data were jotted down during the interview, conversations were recorded, and later important concepts were identified and analyzed. After important concepts were identified, they were analyzed to see relationships among each other in MSWM system [65]. Examining relationships allows a move of tacit knowledge of experts to a more understandable explicit knowledge. A conceptual framework of practical implication of sustainable MSWM in Bangkok constructed by the integration of quantitative SPSS data analysis and qualitative expert interview analysis will be shown shortly in this paper.

IV. RESULTS

The rapid urbanization and economic development taken place in the Asia-Pacific region has led to the increase of MSW generation [43]. MSW is a part of basic urban service and an imperative environmental service [2]. Safe collection and disposal of MSW have been considered as one of the basic services gaining extensive attention from many countries especially developing ones [44-45]. A traditional MSWM system consists of waste trucks, waste bins, and landfills and the kind of system is still in use for waste management in many countries. With the growing issues related to the adverse impacts of landfill disposal, there are some studies about investigating waste diversion methods for sustainable waste management [18-19]. The increase of waste generation and inefficient waste management service are posing serious challenges to the responsible parties, especially local authorities [27-28]. An obstacle that affects a great impact on MSWM system effectiveness is to use inappropriate technologies. Appropriate Technology (AT) referred to technologies used in developing world [63]. The concept has now been applying to many industries, including waste management. Applying this concept, AT is a fraction of solution in achieving sustainable and safe waste management service.

A. Demographic of respondents and general information of MSW management

The results of data analyses show that there are 205 male and 217 female respondents. The majority of respondents have an average income of 10,001 to 20,000 baht or about 300 to 600 $US. Average household size is 3 people per house. In terms of household waste management, 216 (51.2%) respondents do waste sorting. Putting waste in front of their houses for collection and putting waste in public waste bins are two main management methods as there is 96.7% of respondents doing these. Each household generates 1-3 kilograms of waste per day. Interestingly, the results show that only half (48.1%) of them pay for waste collection fee with an average of 21.53 baht per month. Table 1 below shows the residents' perspective on MSW.

TABLE1: GAPS OF MSWM SYSTEM

Respondents' perspective on MSW	Percentage
1. MSW generation should be reduced.	91.7
2. MSW should be managed effectively and efficiently.	90.3
3. MSWM should be effectively operated.	89.3
4. MSW causes environmental problems.	88.6
5. MSW is a great source of alternative energy.	80.6
6. MSW causes social problems.	66.9
7. MSW causes economic problems.	62.8

As shown in table 1, it is delighted to see that almost all respondents think that waste generation should be reduced. The results show a good sign for the City of Bangkok that the residents perceive MSW as a problem, impacts caused by MSW, and are aware of them BMA states that waste reduction should start at changing people's behavior to generate minimum amount of waste. Moreover, other studies show that in Bangkok, waste reduction is one of the sound MSW management methods before landfills. [28, 46-47]. In terms of waste management service effectiveness 55.9% of all respondents think that they receive moderate level of service. Based on the survey results, outstanding problems that need urgent solution are (1) odor smell from waste 68.5%, (2) there is leftover waste 51.2%; (3) waste is not collected on time 39.1%, (4) fallen waste while being transported 31.8%, and (5) there is no waste management service to their area 7.6%.

B. Municipal solid waste management success factors

Looking in terms of factors increasing effectiveness of providing waste management service and contribute to the sustainability of the MSWM system, table 2 shows what factors that the respondents think they can increase MSWM service effectiveness and MSWM system sustainability.

TABLE2: POTENTIAL SUCCESS FACTORS TO INCREASE WASTE MANAGEMENT EFFECTIVENESS

Success factors to increase waste management effectiveness	Percentage
1. Functioned machines and trucks	81.5
2. Strong enforcement on waste disposing of residents	77.3
3. Apply of practical policies in all areas	76.8
4. Apply of appropriate technology	75.8
5. Strong enforcement on waste sorting	75.6
6. Enforcement of stringent waste collection laws	74.2
7. Enforcement of stringent waste transportation laws	72.1
8. Enforcement of stringent waste treatment laws	71.6
9. Qualified staff	66.3
10. Strong enforcement on waste collection payment service	60.5

C. Municipal solid waste management technological challenges

Summarized from table 2, the respondents think that waste management infrastructure, practical policies, and enforceable laws are essential to the effectiveness of waste management. These factors also match the insight information gained from the interview that the most urgent problem imperatively needed to find resolution for a sustainable waste management is suitable infrastructure. If the infrastructure is ready, there should be practical policies and strategies to manage the system. Dwivedy states that successful implementation of waste management other than less generation of MSW; it requires the establishment of appropriate infrastructure [48]. To make the system run smoothly, effective laws should be enforced. The study of Roomratanapun shows law enforcement is the third rank solution to solve waste management problems [49]. Public participation, the main MSW generators, is an essential key for successful MSWM system. Thus, applying human aspect by studying what human need and how they think towards waste management will increase the effectiveness of waste management service and lessen waste management gap.

When asking about level of technology applied to the current waste management system, 214 respondents or 51.7% of the total sample think that the system is operated with technology. However, when asking deeply into details, out of this people think that technology is applied to the system, 44% think that technology is applied at moderate level, 38% think that only a few technology is applied, and 16% think that there is a marginal level that technology is used in waste management system. This result points out that Bangkok residents think that technology should be applied a lot more to increase the effectiveness of waste management system. To see whether technological application impacts to the effectiveness of waste management system of Bangkok, results from chi-square association test show that many technologies are needed to be applied to each stage of waste management. The following table run by SPSS statistics computer program shows influential technologies that affect the effectiveness of waste management system, providing variables are associated in significant sense.

TABLE3: STATISTICAL RESULTS OF CHI-SQUARE TESTS OF ASSOCIATIONS WITH TECHNOLOGIES FOR MSWM SYSTEM

Collection technology	Sorting	Rear truck	Semi-auto truck	GPS	RFID	Built-in compactor truck
Count	156	104	53	41	22	27
Pearson Chi-Square	226.322	130.381	54.124	36.984	21.926	27.25
Contingency co-efficiency	0.591*	0.486*	0.337*	0.284*	0.222*	0.246*

Transportation technology	Effective use of energy	GPS	RFID
Count	85	60	30
Pearson Chi-Square	105.553	62.894	27.549
Contingency co-efficiency	0.439*	0.360*	0.248*

Treatment technology	Recycle	Composting	Landfill	WtE	Incineration	Effective use of energy	Open burning	Gasification
Count	186	156	108	98	62	54	32	8
Pearson Chi-Square	306.419	226.322	133.637	117.162	68.659	58.5	32.711	5.168
Contingency co-efficiency	0.649*	0.591*	0.490*	0.470*	0.374*	0.349*	0.268*	0.110*

* Significant at 1% level

Table 3 shows a preliminary screening of influential technologies that were significantly associated with applying new technology to current waste management at 1% level of significance. With 17 different technologies and the 214 respondents thinking that the system is operated with technology, most of the respondents think that waste sorting and rear truck technologies are essential for waste collection process. Effective use of energy and GPS technologies are needed for waste transportation process. In terms of waste treatment, the respondents think that waste recycle, composting, landfill, and waste-to-energy technologies are important for MSWMS. This result corresponds with the 2012 waste management performance analyzed by the BMA that machines and trucks run ineffectively due to their condition and need to be maintenance [28]. This lessens performance of all waste collection, transportation, and treatment processes.

Many studies have shown that waste generation is the most important factor for successful planning of MSW management system [50]. Technologies are also important for waste transportation as it is the process of taking waste away to be treated. Thus, routes and collection times should be scheduled especially in some areas that are not easily accessible [17, 51]. Waste transfer stations should be enough and located in suitable place, which will not cause environmental problem to the society and wastage to transport waste to remote area [52-53]. UNEP stated that methods for waste treatment in developing Asian countries were commonly dumping and landfill [54]. The respondents have recognized that current treatment methods and technologies are unsustainable. They concerned more on new technologies especially the WtE ones. Experts also added comments that with this high amount of MSW generation, Thailand can have another big power plant each year.

D. Municipal solid waste management technological impacts

To emphasize the importance of application of technology to MSWM system, the following table shows the responding perspective on how the MSWM in Bangkok would be if technology is applied the system.

Table 4 shows the results of explorative factor analysis of the influences of technology on MSWM. There are three factors showing human aspects on the performance of technology on MSWM system. Factor I, technology for cost reduction, shows that applying technology to MSWM can save cost for waste transportation, collection, and treatment and disposal processes. Factor II, technology for social improvement, shows that applying technology to MSWM social, economic, and environmental problems are alleviated with identifying that less amount of staff is required in MSWM processes. Factor III, technology for sustainability, shows that the respondents think that applying technology can make the MSWM system run sustainably and efficiency. It can be seen from the table that these three factors have strong relationship. Factor I and II has a relatively strong correlation at 0.54. Factor I and III has a marginally weak correlation at 0.48. And the correlation between Factor II and III is very strong at 0.61. In terms of applying technology to MSWM, Factor I can best explain respondents' attitudes on the impact of technology for cost reduction on MSWM at 44.17% level, comparing to Factor two that shows the impact on social improvement at 10.99%. Factor III shows that the impact on technology for sustainability of the MSWM system is at 6.45%. Overall, it can be said from the results that, applying technology to be in use will have potential in terms of cost for the optimize profit on reducing expense in waste management, which effects to the whole system on collection, transportation and treatment.

The analyzed questionnaire results represent how Bangkok residents experience and think towards the current waste management service and how it should be. Based on the people attitudes, they are aware that effective and sustainable waste management service is important factors for achieving sustainable waste management. However, with the current performance many, problems exist and are urgently needed to be solved. Not only do socioeconomic and environmental concerns cause ineffective waste management, but also the low level of technology applies to the waste

TABLE4: STATISTICAL RESULTS OF EXPLORATIVE FACTOR ANALYSIS

	Factors		
Items *– Respondents agree if technology is applied with waste management processes, the MSWM system would:*	I Technology for cost reduction	II Technology for social improvement	III Technology for sustainability
- save cost for waste transportation	0.97	-0.03	-0.01
- save cost for waste collection	0.90	-0.04	-0.05
- save cost for waste treatment and disposal	0.81	0.01	0.08
- have less social problems	-0.05	0.84	-0.04
- have less economic problems	0.05	0.80	-0.07
- have less environmental problems	-0.19	0.74	0.13
- require less staff	0.22	0.53	-0.08
- be sustainable	0.01	-0.03	0.87
- be implemented more efficiently	-0.01	0.01	0.85
Correlation between factors I	1.00		
II	0.54	1.00	
III	0.48	0.61	1.00
Total Variance (%)	44.17	10.99	6.45

management operation. The people agree that technology is a vital factor that the MSWM system needs. This paper provides gaps on management system (in table 1) and also suggests success factors and recommended technologies for each management process (in table 2 and 3) to increase the system performance that the waste management needs.

All in all, going towards sustainable MSWM for the City of Bangkok, it is important that all related stakeholders especially the BMA put more effort on improving waste management infrastructure, providing effective and practical waste management strategies. The procedure has to implement in all areas and effectively enforce laws to manage, control, and mitigate the system to ensure that the provided waste management service will surely meet the needs of both service providers and service recipients with friendly environment

V. DISCUSSION

According to the results from both qualitative and quantitative analysis obtained from respondents and experts, practical implication and policy implication are constructed to be applied to MSWM service in Bangkok for a more environmentally friendly and sustainable waste management system.

A. Practical implication for MSWM

Starting with a very important process of waste management, waste collection, effective collection service should be available in all areas of Bangkok as there are some parts of the City that service is unreachable. Waste should be picked up on time as scheduled. Moreover, to prevent bad odor and leftover waste, BMA has to put a serious attention on standards and conditions of waste collection machines and trucks. The other point of concern is qualification and effectiveness in working of employees. Good employees can increase work productivity and eventually result in a reduction of required resources. In terms of technology, appropriate types of trucks should be used in different operational purposes in different areas to ensure that all waste is not left behind or fall during transportation. RFID and camera technologies are another technology that respondents and experts think that they will solve the problems. For example, waste bins in areas that have very high amount of MSW generation should be monitored for a prompt waste collection.

Waste transportation is a crucial process of taking collected MSW from sources of generation to treatment sites. Incorporating expert opinions to improve the effectiveness of waste transportation, time and transportation routes of trucks in each area needs to be improved. The current technologies, GPS and LFD, should be optimally utilized. Waste treatment stations are located 10-110 kilometers away from landfill sites and make time consuming of each round of waste transportation [46]. Thus, BMA should consider having more transfer waste stations to alleviate uncollected waste on time problems. Number of transfer stations should be determined by the maximum distance to make waste economically transferred to stations. Beyond the distance, another transfer station is necessary [66-67]. In Madras city, India, the city is divided into 10 zones and each zone has a transfer station. This saves cost of transportation and also increase waste collection performance [68].

Recycling technology should be highly considered as an initial waste management solution before dumping all waste to landfills. Both residents and experts think that all projects launched by BMA did not attract people's attention and are not successful. Those projects should be continuously promoted and consistently encourage public to participate in. The residents would like to be educated and guided for doing waste reduction properly with some supports or incentives provided. Waste treatment technology should go in the way providing benefits to all stakeholders and also including the environment and society as a whole for well human being. Lastly, thermal waste treatment technology should be considered as an alternative waste treatment method, instead of sanitary landfill.

The respondents and experts do not think that achieving sustainable MSWM in Bangkok will successfully happen in a short or medium term. However, they think that it is quite possible to be in long-term. The people have put more attention on environmental awareness. They perceived that waste has caused eco-socio-environmental impacts. This is a good sign for BMA to seriously start improving the MSWM system.

B. Policy implication for MSWM

Having only effective waste management is not enough for making a city have a sustainable waste management system; also it does not ensure that effective service will be provided to all residents. Practical policy is very important to set direction for the system. From the analyses of this paper, the results show that there should be a master plan for MSWM that is applicable and practical to all residents in all areas at all levels. The plan should be concrete to make all processes of waste management system run efficiently.

Budget allocation policy is another essential concern for better waste management service. Experts say that technologies are very important. Once there is technology in-use, it is important to optimally utilize. Moreover, research and development on MSWM is an important key that helps system run sustainably. In terms of social perspective, respondents and experts suggest that there be policy focusing on public health condition. The policy is for people who work directly with waste and those who have risk on it. Another solution is having education policy. This policy should educate students in school of how to deal with different types of waste. Then there should have projects to promote waste management methods, for example, promoting waste reduction at source to the public to encourage people to do waste sorting before disposing.

Above all, both respondents and experts suggest that all stakeholders should be involved in waste management system. They would like to be part of setting goals that contribute mutual benefits to all related parties. Correspondingly, they think that pilot projects should be implemented. Furthermore, when the projects are successfully implemented, the method of management should be extended to other parts. Additionally, after having appropriate waste management infrastructure, the government should have policy to ensure that every process is appropriately operating and all people respond correctly. Most of all, there should be effectively enforceable law applied to all parties and all processes of waste management.

VI. CONCLUSION

The thorough primary and secondary analysis of this paper has demonstrated essential findings with insightful information that can be applied to make a better waste management system for MSWM in Bangkok. First, technological challenges fall into the need of proper technologies, technology transfer, and well-maintained machines and waste trucks. Second, there is an urgent need of effective strategic waste management policy that is practical to all areas of the City. Qualified and trained staff is an important factor to make the system run effectively and operate uninterruptedly. Third, effective laws and regulations should be effectively and consistently enforced to all people at all levels.

Focusing on technology issue, applying an appropriate technology to waste management system has several points to concerns [53]. Firstly, it is imperative to meet the basic needs of all stakeholders, especially the people in remote areas. Many modern technologies aim towards satisfying desire, wish or pleasure are examples of inappropriate technologies [54]. Secondly, it has to be sound that the technology needs to meet technical requirements and standards, function properly, and go in line with local conditions [55]. Thirdly, it is flexibility to have a technology to work in different situations and places of the City at all levels [56-57]. Fourthly, an appropriate technology should meet local capabilities on the basis of local resources. This is more likely a more affordable and sustainable way of doing waste management [57]. Fifthly, the technology has to be affordable by the City [58]. This is a very challenging constraint for many cities including Bangkok. The BMA has decided to choose incineration instead of a more promising environmentally friendly technology, which is gasification with high investment and skills needed [59-60]. Furthermore, it is not essential that the technology be cheap if it fits the city and all stakeholders' agreement. [61-62]. Sixthly, for sustainability, the technology has to be environmentally, socially, economically, and locally sustainable since it must not cause any harmful impacts to the environment, society, economy and must follow people's need without compromising future generations [58]. It has to ensure that stakeholders are capable to maintain all functions properly [55]. Applying these six concerns to technology transfer mechanisms for waste management system is more important and complicate than selecting a proper technology to apply to waste management process [61-64].

It is suffice to say that technologies are very important and have significant impact on waste management effectiveness. This paper identifies waste management gaps and successful factors for a sustainable MSWM technology transition for the City of Bangkok, Thailand. However, technology is only a part of solution in achieving sustainable and effective waste management system. There is no perfect technology or solution that is suitable for all circumstances in all areas. It is essential to address others issues such as cooperation and teamwork to all related stakeholders, multi-disciplinary integrated approaches, and service sustainability to manage waste.

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