An Assessment Tool for the Sustainability of Municipal Solid Waste Management in Thailand

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ชื่อวิทยานิพนธ์	เครื่องมือประเมินความยั่งยืนของระบบการจัดการมูลฝอยชุมชนในประเทศไทย
ผู้เขียน	นางสาวจรีรัตน์ สกุลรัตน์
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ปีการศึกษา	2553

บทคัดย่อ

งานวิจัยนี้มีจุดประสงค์เพื่อสร้างเครื่องมือช่วยประเมินความยั่งยืนของระบบจัดการมูลฝอยชุมชน ภายใต้บริบทของประเทศไทย เพื่อเพิ่มศักยภาพขององค์กรปกครองส่วนท้องถิ่นในการวางแผนการจัดการมูลฝอย และเพิ่มประสิทธิผลของระบบการจัดการมูลฝอยชุมชนในปัจจุบัน องค์กรปกครองส่วนท้องถิ่นส่วนใหญ่ของประเทศไทยไม่สามารถออกแบบระบบการจัดการมูลฝอยของชุมชนที่เหมาะสมสำหรับพื้นที่รับผิดชอบได้ด้วยตนเอง สาเหตุหนึ่งเนื่องจากส่วนใหญ่ไม่มีเครื่องมือสำหรับช่วยจัดการกับความซับซ้อนของระบบการวางแผน ดังนั้นเครื่องมือใหม่จึงถูกสร้างขึ้นเพื่อช่วยองค์กรปกครองท้องถิ่นในการปฏิบัติขั้นตอนแรกของกระบวนการวางแผน นั่นคือ ประเมินความยั่งยืนของระบบการจัดการมูลฝอยในปัจจุบันเพื่อจะได้เลือกวิธีการปรุบปรุงที่เหมาะสมที่สุดเพื่อให้ระบบมีความยั่งยืนมากขึ้น โดยเครื่องมือประเมินที่สร้างขึ้นนี้คำนวณคะแนนที่แสดงถึงระดับความยั่งยืนของระบบการจัดการวางแผนมูลฝอยในปัจจุบันของแต่ละองค์กรปกครองส่วนท้องถิ่น

เครื่องมือช่วยที่สร้างขึ้นประเมิน 4องค์ประกอบหลัก ที่มีความสำคัญต่อความยั่งยืนของระบบการจัดการมูลฝอย ซึ่งประกอบด้วย (1) ระบบทางวิศวกรรม (2) ศักยภาพขององค์กรปกครองส่วนท้องถิ่น (3) การมีส่วนร่วมของชุมชน และ (4) การร่วมมือกันระหว่างองค์ประกอบหลักทั้ง 3ข้างต้น โดยคะแนนของแต่ละองค์ประกอบถูกคำนวณและนำมารวมกันเพื่อเป็นคะแนนที่แสดงระดับความยั่งยืนของระบบการจัดการมูลฝอย สูตรการคำนวณ มาตรฐานและแนวปฏิบัติที่มีอยู่ในปัจจุบัน ถูกนำมาปรับปรุงเพื่อใช้เป็นเกณฑ์การประเมินประสิทธิภาพของแต่ละองค์ประกอบ อย่างไรก็ตาม ได้มีการสร้างวิธีการประเมินใหม่ขึ้นในงานวิจัยนี้ด้วย โดยคำนึงถึงวิธีการปฏิบัติงานจริง และ ความสามารถในการหาข้อมูลสำหรับการวิเคราะห์ขององค์กรปกครองส่วนท้องถิ่น

ผลการศึกษาแสดงให้เห็นว่าวิธีการประเมินที่พัฒนาขึ้นทั้งหมดสามารถสื่อถึงระดับความยั่งยืนของระบบการจัดการมูลฝอยของแต่ละองค์กรปกครองส่วนท้องถิ่นที่ปฏิบัติอยู่ในปัจจุบันได้เป็นอย่างดี โดยองค์กรปกครองส่วนท้องถิ่นที่มีคะแนนความยั่งยืนสูง มีระบบการจัดการมูลฝอยที่มีประสิทธิภาพมากเช่นกัน ผลการศึกษายังแสดงให้เห็นว่า ระบบทางวิศวกรรมมีความสำคัญต่อการเพิ่มประสิทธิภาพของระบบการจัดการมูลฝอยชุมชนมากที่สุด ตามด้วยศักยภาพขององค์กรปกครองส่วนท้องถิ่น การมีส่วนร่วมของชุมชน และการร่วมมือกันขององค์ประกอบที่เกี่ยวข้อง ตามลำดับ

และยังพบว่า ศักยภาพการในวางแผนขององค์กรปกครองส่วนท้องถิ่นสามารถเพิ่มขึ้นได้หากมีการใช้เครื่องมือช่วย ดังนั้น ครื่องมือประเมินความยั่งยืนของระบบการจัดการมูลฝอยชุมชนในประเทศไทยที่พัฒนาขึ้นนี้ จะช่วยให้องค์กรปกครองส่วนท้องถิ่นสามารถประเมินจุดอ่อนของระบบการจัดการมูลฝอยได้ถูกต้องมากยิ่งขึ้น และสามารถเลือกวิธีการแก้ไขปัญหาที่เหมาะสมและถูกต้องมากขึ้น เพื่อมุ่งสู่การมีระบบการจัดการมูลฝอยชุมชนที่ยั่งยืนในพื้นที่

เครื่องมือประเมินความยั่งยืนของระบบการจัดการมูลฝอยชุมชนในประเทศไทยนี้ถูกพัฒนาขึ้นในรูปแบบของโปรแกรมคอมพิวเตอร์ด้วยโปรแกรม Microsoft Excel ซึ่งเจ้าหน้าที่ขององค์กรปกครองส่วนท้องถิ่นสามารถใช้งานได้ง่าย และจะคำนวณคะแนนระดับความยั่งยืนของระบบการจัดการมูลฝอยชุมชน ให้แต่ละชุมชนได้อย่างรวดเร็ว

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ABSTRACT

This research developed a new assessment tool to evaluate the sustainability of MSW management system based on Thai context in order to enhance the planning capability of local authorities and consequently the efficiency of MSW management system. At present, the majority of local authorities in Thailand are unable to design appropriate MSW management system for this area by themselves. Most of them lacked of tool to handle the complication of the planning process.

Thus, the proposed assessment tool was designed to assist local authorities in the first planning step or to evaluate the current performance of MSW management system subjected to the sustainability concept before proper actions can be designed. The score, illustrating the status of current MSW management system as compared with the sustainability goal was calculated.

The proposed assessment tool evaluates four components that significantly contribute to the sustainability of MSW management system including the Engineering system, the Local authority's capability, the Public participation, and the Collaboration. The score of each evaluation component was calculated and combined to determine the sustainability score. Available mathematical formula, standards, and guidelines were adopted to evaluate each component. New evaluation methods were also developed. These evaluation methods were developed concerning the actual practices and the ability of local authority to acquire input data.

The study result illustrates that the developed assessment methods to determine the sustainability score of each MSW management system were well represented the actual practices. Local authorities with higher sustainability score had higher efficient MSW management system. The findings also confirmed that the local authorities' capability is the most important component to enhance the efficiency of MSW management followed by the public participation, and the collaboration. Importantly, the planning capability of local authority can be enhanced if the support tool is provided.

Thus providing the developed assessment tool will significantly help local authorities to evaluate the performance of existing MSW management more precisely. More appropriate improvement actions can be expected. The developed assessment tool was subsequently developed on Excel Spreadsheet to calculate the sustainability score of current MSW management system.

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CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

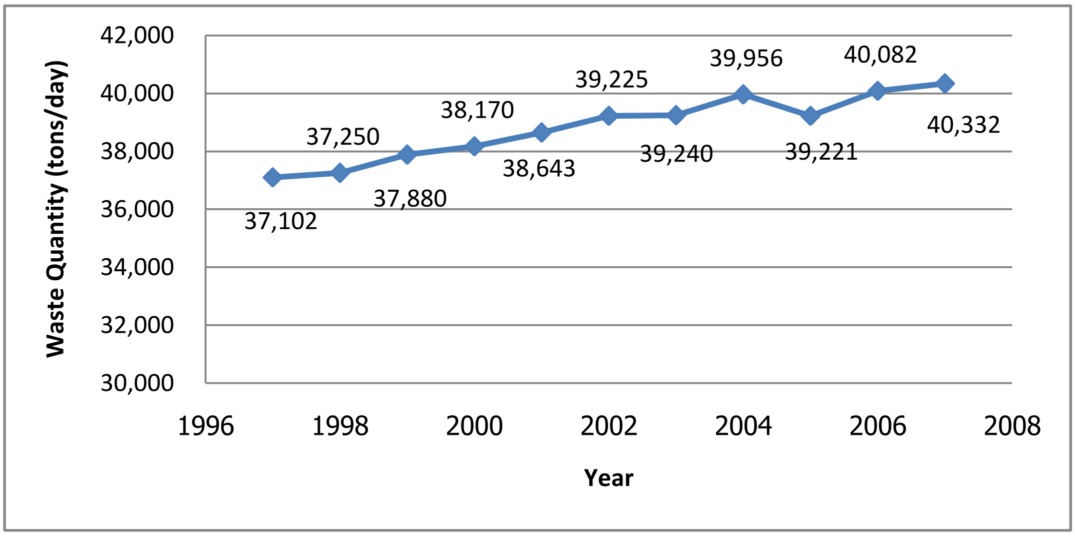
Solid waste from residential and commercial areas, commonly known as municipal solid waste (MSW), has always been of great concern to the public. MSW is always visible to them and has characteristics that threaten aesthetics, the environment and public health, which draw unfavourable attention to it. These characteristics require actions to remove such materials from areas where people live and/or work in a timely manner and to dispose of them in an environmentally friendly manner, to minimise the harmful impacts. A series of actions for handling MSW from generation to final disposal is termed an ***MSW management system”***.

The structure of MSW management systems has improved since the discipline first came to be studied and organised. In addition to the above requirements, one of the ultimate goals of MSW management systems, to date, has been to reduce the amount of MSW going to final disposal sites landfills as much as possible by minimising generation rates and maximising recovery. MSW is now seen as a potentially valuable resource that can be utilised to reduce the consumption of natural resources. Because of this, MSW management systems now usually include source reduction, source separation and storage, collection, transport/transfer, transformation/treatment (e.g., recycling, composting and incineration) and disposal processes.

Local authorities are commonly responsible for MSW management system in their areas and so their management capability is crucial for the success of the system. Local authorities must be able to plan or design MSW management systems suited to local conditions, and then to implement them as planned. MSW problems change with time and planning capability is essential within the authorities so that the local MSW management system can be changed accordingly in order to maintain its performance. Thorough evaluation is important to ensure that technologies or activities suited to existing MSW characteristics and community requirements are selected. If this is not achieved, MSW problems might continue and/or reappear.

1.2. STATEMENT OF THE PROBLEM

MSW has been one of the key environmental issues in Thailand. Its quantity has been increasing annually as shown in Figure 1-1 according to the state of pollution reports by the Pollution Control Department (PCD). In 2007, the average generation rate across the country was 0.6 kg/cap/day (1.5 kg/cap/day in Bangkok, 0.7-1.0 in municipal areas and 0.4 elsewhere) (PCD 2007). The total quantity of waste generated has increased by 10% over the past ten years (from 37,102 tonnes per day in 1997 to 40,332 in 2007) (PCD 2007). Of that total, half was generated in urban areas (21% in Bangkok Metropolitan and 34% in municipal areas) while the remainder (45%) was generated outside municipal areas. Local authorities are responsible for MSW by law.



Source: PCD 2006; 2007; 2008

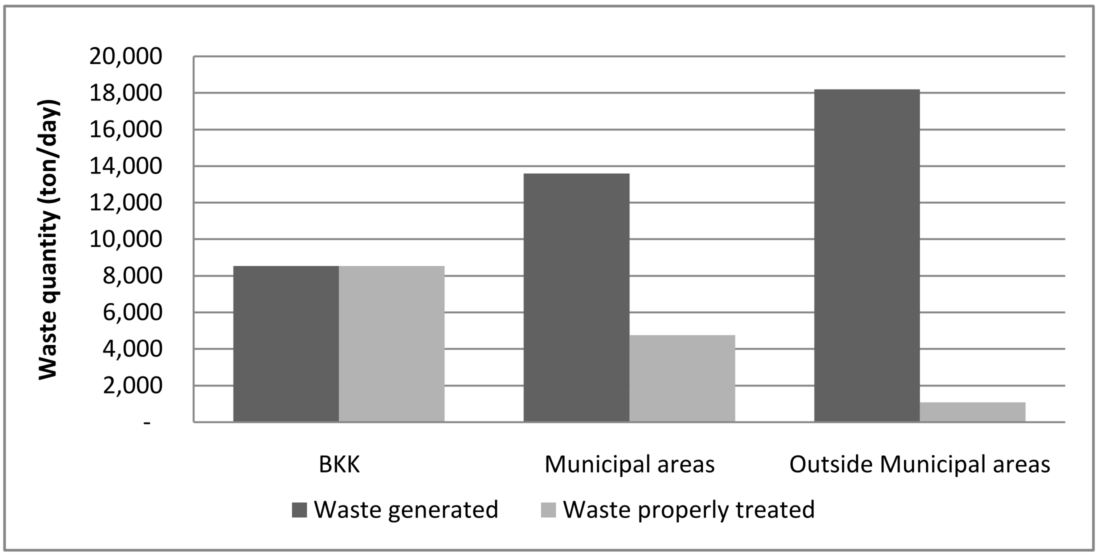
Figure 1-1: Annual rates of MSW generation in Thailand

Current Thai national MSW management goals, addressed in the *Policy and Plan for the Enhancement and Conservation of National Environmental Quality 1997-2016* (ONEP 1997) are

1. to control the rate of MSW generation to not more than 1.0 kg/capita/day;
2. to recover not less than 15 % later revised to 30% of the total MSW generated;
3. to increase MSW collection efficiency to 100% in municipalities and 90% outside them; and
4. to ensure that each province has a master management plan for sanitary waste disposal and that every local authority has a proper MSW disposal system.

As a result, numerous campaigns have been promoted widely to encourage public participation in MSW management programmes particularly source separation activities. Larger budgets are being made available to all local authorities from various sources such as the Environmental Fund. Extensive research on MSW management technologies is in hand in Thailand, along with other measures. However, rooms for improvements are observed.

In 2007, only 60% of the generated waste was collected; comprising 100% in Bangkok, 70-80% in municipal areas, and 20-30% elsewhere. Although all of the collected MSW from Bangkok metropolitan area went to sanitary landfill, only 35% and 6% of the MSW collected, respectively, in municipal areas and outside them was treated properly through recycling, composting, incineration, and sanitary disposal as shown in Figure 1-2 (PCD 2007). The remaining material was still dumped in the open and without proper controls. Aesthetic damage, air quality impairment, and surface- and ground- water contamination are common complaints. Other effective measures are needed to address the current situation and to move towards sustainable MSW management system in Thailand.



Source: PCD 2007

Figure 1-2: Efficiency of MSW management in Thailand in 2007

The key reason of current deficits is that local authorities are unable to design effective MSW management system suitable for their areas by themselves. Various cases, the problem sustains although sufficient resources were available. Adopting efficient MSW management systems of other cities were common practices which were eventually shutdown as they did not work as they should. Such failures consequently led to low levels of public participation in MSW campaigns (OPSI 1997).

Although each local authority is now required, under the Regulations of the Ministry of Interior with regards to making and coordinating the relevant development plan of local administration B.E.2548, to prepare its development plan where solid waste management issue is addressed, no measures have been implemented to ensure that proper analysis is carried out and MSW management system addressed in the development plan suitable for MSW problem in their areas. The problem remains. Therefore, measures to ensure effective analysis so that local authorities can choose suitable MSW management systems by themselves are required to address the current MSW problem.

The provision of an analysis support tool has proved to be one of useful measures in various countries in order to enhance the effectiveness of selected MSW management system. Several computer-based analysis tools have been developed and available in recent years for designing MSW management. The main application of these tools is to evaluate the performance of MSW management system. Economic and environmental aspects are common evaluation criteria with few consider social aspect.

Interestingly, it is found that individual performance subject to each criterion such as cost, environmental impact, or efficiency is presented when a single MSW management system is analysed, while overall performance is commonly determined when various MSW management systems are analysed to select the best choice among other options. However the overall performance is determined comparatively among the choices. No tool is available for analysing the overall performance of a single MSW management system.

Moreover, these analysis tools have come from developed countries, where conditions are often different from those in a country like Thailand. These differences include the waste characteristics, technologies available, socio-economic structure(s), and particular local capacity. The applicability of these available tools in Thailand is thus doubtful, at least to some extent. The capability of local staff to use these tools is also suspicious since engineers are rarely working in local authorities and the available data is very limit. Although a computer-based tool called *Solid Waste Expert System* as de eloped at one time to assist Thai local authorities with the MSW planning process, it recommended management systems based solely on the waste characteristics. It is no longer in use.

Thus, a tool for designing MSW management at local level suited to Thai context should be developed as a measure to build up the planning capability of local authorities and consequently to increase the chance of achieving sustainable MSW management systems nationwide. Considering the common planning process, the first and probably the most important step is to understand the current status whether the objectives of sustainable MSW management system are fulfilled before proper solutions can be designed. A new tool to improve the efficiency of this planning step would be useful for local authorities in Thailand.

1.3. RESEARCH OBJECTIVE

The ultimate goal of this research is to enhance the efficiency of MSW management system in Thailand by improving the MSW planning capabilities of local authorities in Thailand. Thus, the research objective is to develop a new tool to assess the current MSW management systems subject to the sustainability concept and Thai context. More comprehensive MSW planning is expected at local level, resulting in more appropriate actions for managing their MSW. The research hypothesis is that

> *The weakness of current MSW management systems in Thailand is caused by the low planning capability of local authorities. The planning capabilities could be improved if a suitable support tool was provided. New analysis tool suitable for the capability of local authorities in Thailand is necessary.*

Taking the sustainable concept into account, the proposed assessment tool evaluates the efficiency, economic, environmental and social performances of the existing MSW management system. The result is presented in terms of sustainability score, illustrating the level of current MSW management system as compared with the sustainability goal. The gap for achieving sustainable MSW management system is illustrated. In other words, system with higher scores has more chance of achieving sustainable MSW management. The sustainability score is also useful for classifying the group of local authorities in Thailand based on the performance of their MSW management system. Appropriate improvement policy for each group can be designed.

In summary, the main contribution of this research is a new method or tool for evaluating the sustainability of any given MSW management system, in the Thai context. It is anticipated that better decisions will be achieved, because of this, at the local level. The result would be a case study for developing countries, where designing suitable MSW management systems is also a common problem (UNEP 2000; Diaz 2009). In addition to this, the significance of the planning capability at the local level to successful MSW management is illustrated. More attention can then be drawn to this issue to solve MSW problems.

1.4. LIMITATION OF THE STUDY

In general, solid waste generated from community is known as municipal solid waste (MSW) because it is commonly collected by local authority, called municipality. However, the term MSW used in this research means solid waste from community collected or managed by local authorities even though some of them are not named as municipality. At present, local authorities in Thailand are divided into seven forms, including Nakhon municipality (NM), Muang municipality (MM), Tambon municipality (TM), Tambon Administrative Organisation (TAO), Provincial Administrative Organisation (PAO), City of Pattaya (CP), and Bangkok Metropolitan Administration (BMA). Role and structure of each form are slightly different.

At present, there are 23 local authorities in the form of NM, 140 in the form of MM, 1,456 in the form of TM, 6,157 in the form of TAO, 75 in the form of PAO, one in the form of BMA, and one in the form of CP. In total, there are 7,853 local authorities in Thailand (DOLA 2009). Although the performances of all forms of local authorities are concerned, PAOs are excluded from this research because at present they do not directly regulate MSW management systems, but facilitating other forms of local authorities in the provinces. The BMA and CP are also excluded due to the difference in their organizational and management structures to MSW management.

1.5. THESIS STRUCTURE

According to the research problem and objective presented in this Chapter, the details of other chapters are as followed. Chapter 2 reviews MSW management systems of various countries to identify common factors that affect the efficiency or sustainability of MSW management systems. Proper MSW management planning system at local level and current MSW planning support tools are subsequently reviewed. These information are used for the development of the new assessment tool.

Chapter 3 presents the research method used to determine the sustainability score of each MSW management system and to develop an MSW assessment tool for local authorities in Thailand. This incorporates the conceptual framework, and methods of evaluation and verification. Chapter 4 illustrates the details of the developed MSW assessment tool and discusses the effectiveness of the developed assessment tool and the significance of MSW planning capability at local level with respect to the performance of MSW management. Chapter 5 concludes the research outcome.

CHAPTER 2

LITERATURE REVIEW

KEYS FOR SUSTAINABLE MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM

2.1 INTRODUCTION

By nature, MSW can cause aesthetic damage, air quality impairment, global warming, water resources contamination (both surface and groundwater), and drainage clogging. These impacts will finally affect environmental quality and human health. This consequently calls for actions known today as ***MSW management system*** to ensure that the waste is properly controlled while unavoidable impacts are kept at acceptable levels at all times. The structure of MSW management system has been changed since the early stage. From simple collection and disposal methods, achieving a sustainable MSW management system is now a target of all countries.

The purpose of this chapter is to identify the concept of sustainable MSW management as well as technologies and measures, being implemented in the world for accomplishing sustainable MSW management system in which Thailand can learn and adapt to its current situation. The first section of this Chapter presents the general background of Thailand relevant to the management of MSW, including geography and administrative structures. The current MSW management system is briefly described. MSW management of various countries both developed and developing countries are then studied to identify the sustainability evaluating indicators that will be used in the proposed MSW assessment tool for local authorities in Thailand.

2.2 GENERAL BACKGROUND OF THAILAND

Thailand is situated in the tropics in the centre of the mainland of Southeast Asia with an area of 513,115 square kilometres divided into five regions: north, northeast, central, east and south based on geography. Bangkok, the capital city, is located in the central region. The climate of Thailand is humid and the average annual rainfall is 1,550 millimetres. The average temperature in the uplands varies significantly from summer (33-38^{o}C) to the cool season (15^{o}C) while in the south it is about 26-27^{o}C throughout the year as closer to the equator (PRD 2000). The population of Thailand was approximately 63.4 million (DOPA 2009) at the end of 2008 with about a 0.5% per annum growth rate.

Thailand has had a constitutional monarchical regime since 1932 in which the king remains the head of state, but the sovereign power (legislative, executive, and judicial powers) is exercised through the national assembly, the cabinet (council of ministers) and the courts respectively (PRD 2000). Under the current Constitution of the Kingdom of Thailand 2007, the national assembly or parliament consists of two chambers: the House of Representatives (480 members) and the Senate (150 members) (Wikipedia 2010). The executive power is wielded by the cabinet, headed by the Prime Minister and 35 ministers from 20 ministries as described in Figure 2-1.

To ensure that people living outside the capital, Bangkok, are served adequately, the country is then divided into administrative provinces. At present, there are 75 provinces and Bangkok. The Minister of the Interior appoints a governor as a representative to head the administration of each province. Other ministries also have branch offices in the provinces. Each province is further divided into a number of districts, further divided into subdistricts or tambons, consisting of a number of villages. Key functions of the provincial administrative body include maintaining law and order, preventing and suppressing communicable diseases, providing for education and training, arranging communication networks between provinces, districts, subdistricts and villages, and other duties formulated from time to time by the Ministry of Interior.

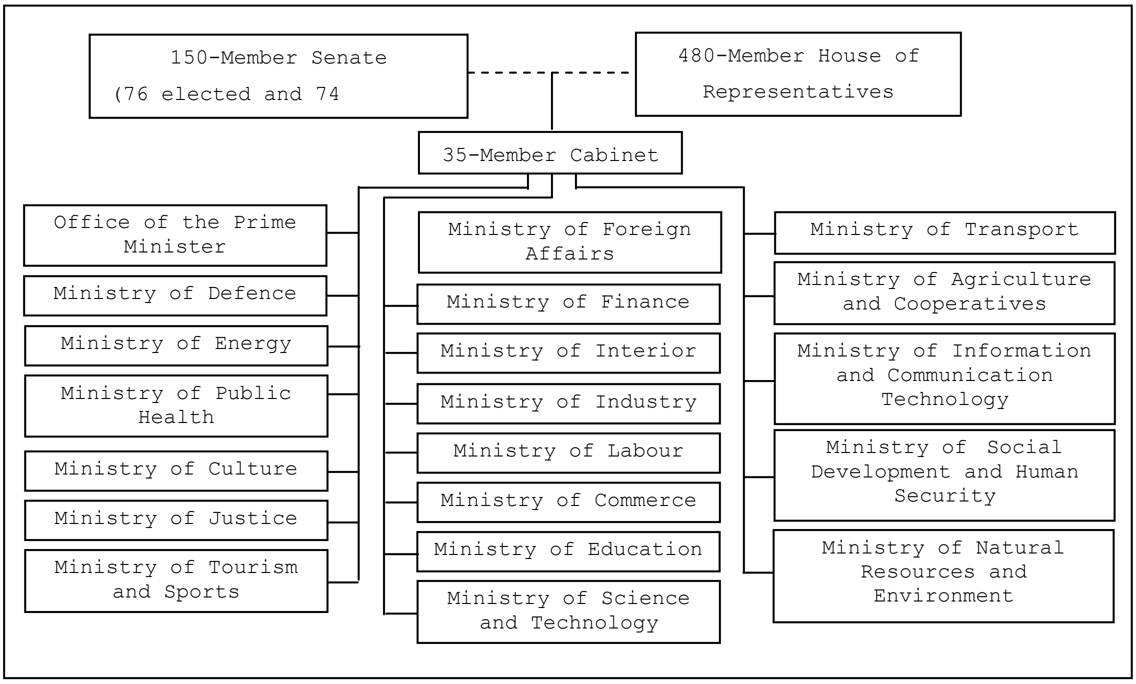


Figure 2-1: The central administrative body of Thailand

At tambon level, a local administrative body or local authority, chosen through local election, is also established, responsible for the affairs at tambon level including providing and maintaining infrastructure such as roads and waterways, keeping roads, pathways and public places clean, and disposing of solid waste. As a result, each tambon is under the authority of both provincial and local administrative bodies. The structure of local authority generally resembles the division of the central government. A summary of the administrative structure of Thailand is given in Table 2-1.

Table 2-1: Administrative structure of Thailand

Region	Administrative level	Administrative Body	
		Legislative body	Executive body
Country	Central Administration	National Assembly	Cabinet (Central Government)
Province	Provincial Administration	-	Governor
District	Provincial Administration	-	District Officer
Subdistricts (Tambon)	Provincial Administration	-	Subdistrict Chief
	Local Administration	Council	Executive Board (Local Government)

Currently, local administration or local authority in Thailand is classified into seven forms including the so-called Tambon Administrative Organisation (TAO), Tambon Municipality (TM), Muang Municipality (MM), Nakhon Municipality (NM), Provincial Administrative Organisation (PAO), Bangkok Metropolitan Administration (BMA), and City of Pattaya (CP). They differ in the form of the executive board as summarised in Table 2-2 and each of these forms operates independently from the others (UNESCAP 2002). In 2008, there were 23 local authorities in the form of NM, 140 in the form of MM, 1,456 in the form of TM, 6,157 in the form of TAO, 75 in the form of PAO, one in the form of BMA, and one in the form of CP. In total, there were 7,853 local authorities in Thailand (DOLA 2009).

Rural areas are administrated by TAOs or PAOs while urban areas are under the jurisdiction of municipalities, the City of Pattaya, and the Bangkok Metropolitan Administration. TAO is the lowest and most localised form of administration in Thailand while Nakhon municipality has the highest status of local authority in Thailand. PAO strengthens cooperation among all the local authorities in the province. BMA is designed and used only for the capital city, Bangkok, where most of the country’s resources are consumed and all important economic activities as well as political, educational and cultural institutions and international links occur. This requires Bangkok to have a more sophisticated local administrative system than might be the case elsewhere in the country. This is similar to the case of Pattaya city.

Table 2-2: Summary of Local Administration Forms in Thailand

Forms of Local Authority	Area	Population Size	Legislative Board	Executive Board
1. Tambon Administrative Organisation (TAO)	Rural	Population varies to size	Elected council for a 4-year term, at least 6 members	Chief Executive, elected by the council
2. Municipality	Urban		Elected council for a 4-year term	Mayor, elected by the council
2.1 Tambon Municipality		Population > 7,000 Pop. Density 1,500/km^2	12-member	Mayor, elected by the council and 2 deputies appointed by the Mayor
2.2 Muang Municipality		Population > 10,000 Pop. Density 3,000/km^2 The city hall is located	18-Member	Mayor, elected by the council and 2 deputies appointed by the Mayor
2.3 Nakhon Municipality		Population > 50,000 Pop. Density 3,000/km^2	24-Member	Mayor, elected by the council and 4 deputies appointed by the Mayor
3. Provincial Administrative Organisation (PAO)	Rural and Urban		Elected council for a 4-year term, 24-48 member	Chief executive
4. Bangkok Metropolitan Administration (BMA)	Urban		Elected assembly for 4-year term, 38 member (one from each district)	Governor, directly elected by popular votes; and 4 deputies appointed by the Governor
5. City of Pattaya	Urban		City council, 9 elected and 8 appointed for 4-year term	City manager, employed on 4-year contract, and 2 deputies appointed by the City manager

Source: UNESCAP 2002

Each local authority is now required under the Regulations of the Ministry of Interior with regards to making and coordinating the relevant development plan of local administration B.E.2548 to prepare its strategic development plan, where solid waste management issue is addressed. The development plan is subsequently transferred into three years plan, and operating plan. Regarding MSW management issue, the actions addressed in the plans must be in line with the national polices of various ministries particularly Ministry of Natural Resources and Environment.

In Thailand, environmental management is under the Ministry of Natural Resources and Environment (MNRE). The main responsibilities of MNRE are to conserve natural resources for sustainable development, to protect the environmental quality, to rehabilitate the degraded natural resources for future development, and to boost institutional capacities to manage the environmental quality (MNRE 2005). Key authorities established under the MNRE directly responsible for the national environment are the Office of Natural resources and Environmental Policy and Planning (ONEP), the Pollution Control Department (PCD), and the Department of Environmental Quality Promotion (DEQP).

The ONEP, PCD and DEQP have collaboratively formulated the national policy for MSW management named "*Policy and Plan for Enhancement and Conservation of National Environmental Quality 1997-2016*" under the environmental legislation titled *Enhancement and Conservation of National Environmental Quality Act 1992*. The national goals for MSW management have been set up, in which MSW management plan of each local authority should follow including (ONEP 1997):

1. to control the rate of MSW generation to not more than 1.0 kg/capita/day;
2. to recover not less than 15 % later revised to 30% of the total MSW generated;
3. to increase MSW collection efficiency to 100% in municipalities and 90% outside them; and

4. to ensure that each province has a master management plan for sanitary waste disposal and that every local authority has a proper MSW disposal system.

2.3 CURRENT MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM

As mentioned earlier, local authorities are by law responsible for regulating MSW management system. In most cases, the responsibility is divided into two divisions. The Public health and Environmental division is responsible for the collection related activities: container provision, separation, street sweeping, and transport. Meanwhile, the Public work division is responsible for processing and disposal related activities.

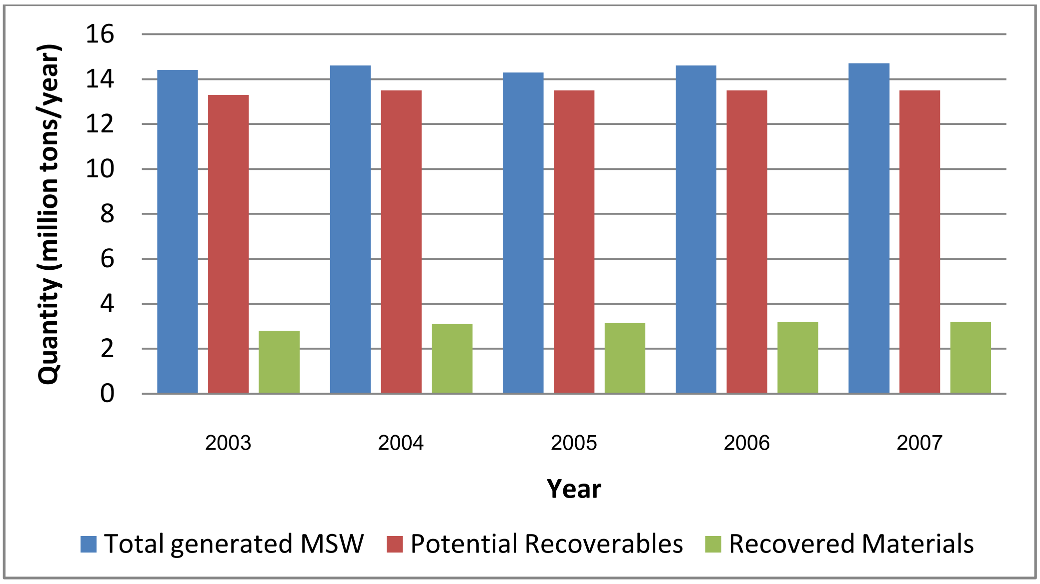
Major components of MSW in Thailand are food waste, paper, plastics, glass, and ferrous metals. Hazardous materials such as batteries and fluorescent bulbs are also found, due to the absence of a proper separation system. The density of collected MSW in Thailand varies from 100 kg/m^3 to more than 300 kg/m^3 (Danteravanich 1998). The average moisture content of MSW in Thailand is 55% on a wet mass basis, but 70% can be reached in some areas (Thongnark 1997) due to the tropical climate with high humidity.

At present, the proportion of properly treated MSW in urban area is higher than rural areas because more knowledgeable staff and budget for fundamental services are available. Overall collection efficiency in 2007 was 60%. The average MSW collection rate in municipal areas was 70-80% (PCD 2007). While, that for rural areas was about 20-30% (PCD 2007). Only BMA has reached almost 100% collection efficiency. There are several reasons for the deficiencies. In urban area, the main causes include traffic jams, narrow roads, unsystematic routing, and the absence of collection crews. Common problems in rural area are inadequate containers requiring more time at each pickup point gathering scattered litter into the vehicle, insufficient collection vehicles, unsystematic routing, and shortage of skilled labour.

Informal recovery activities are however common in both urban and rural areas. In 2007, about 22% of MSW generated was recovered (PCD 2007). Recyclable materials are usually packed in plastic bag and hang on the back of the regular collection vehicles to provide extra income for the collection crews. Scavengers or so called “Saleng” also buy materials from residents, sort it out from waste containers, and recover it from open dumps. Recovered materials are sold to middlemen, who have shop in almost every province. The refuse dealers separate the waste materials further and sell them to appropriate processing or remolding mills and factories (Danteravanich and Darnsawasdi 1999; PCD 2000).

At present, the business of buying recyclable materials is widely established. This is an essential factor in stimulating waste separation activities in Thailand. Waste banks have also been established to buy waste from the members for sale to material processing plants. Community-based composting units are widely promoted. The most common composting method is by windrows. Liquid fertiliser production is another form of composting, using effective micro-organisms (EM) and molasses (PCD 2004).

Although more waste is being recovered, the proportion is still low compared to the amount that has the potential for recovery, as shown in Figure 2-2. The recovery rate includes materials with potential for both recycling and composting. Formal source separation systems for waste are not yet in place in Thailand and so separate collection systems for different types of wastes are not provided (Danteravanich and Darnsawasdi 1999).



Source: PCD 2003; 2004; 2005; 2006; 2007

Figure 2-2 Recovery activity of MSW in Thailand from 2003-2007

In fact, segregated wastes are often mixed together again. Moreover, there are no materials recovery facilities or full MSW recycling system operated in any city. Data on the physical components of MSW are not commonly studied or recorded. This is a basic need for designing proper recovery systems for the community. Compaction of wastes during the collection process makes separation of recyclables difficult and lowers their values (Danteravanich and Darnsawasdi 1999).

Contamination with heavy metals then limits the potential for composting despite the high proportion of organic waste and available technology. Only 5% of the compostable content was utilized in 2002 (PCD 2002). Beyond this, no market for compost is available as yet. Cooperation within the community in separating activities is inadequate. According to research on public participation by Office of Permanent Secretary for Interior (OPSI) 1997, a major reason for residents not participating in source separation programs was their dissatisfaction with the performance of local authorities. Factors cited include impolite collection crews, irregular and poorly scheduled collection services, and lack of a separate collection for sorted materials.

Only 36% of remaining MSW was properly disposed in 2007, 100% in Bangkok, 37% in municipal areas, and 6% in rural areas. The difficulty in acquiring suitable land for a new controlled (sanitary) landfill site due to public opposition has forced many local authorities to continue to use existing open dumps or uncontrolled sites. The public opposition could be due to the lack of public confidence in the ability of local authorities to control landfills properly. In many cases, the operation of the facility is unreliable as dumped waste is left uncovered at the end of the working day. Financial limitations may also be another barrier to obtaining a suitable disposal site in some regions.

From the literature study and the field observation, the factors that obstruct local authorities in Thailand both in urban and rural areas to achieve effective MSW management systems are related to three main aspects:

1. the management capability of local authority
2. the availability of budgets and facilities, and
3. the participation of public

Low management capability within local authorities is a significant issue in the provision and regulation of the services daily. Shortage of skillful staff has resulted in the absence of comprehensive planning activities, where exiting situation of MSW is analysed and proper resources and manner needed to handle these MSW is selected. This deficit has contributed to the problems of unsystematic routing, irregular services, and maintenance of system efficiency. Moreover, efficiencies in operation are not optimised although sufficient facilities and public awareness are available. Clear regulations and policies are then not developed. Suitable land for disposal in the long-term is not prepared.

Limited budgets and technologies are other factors contributing to poor performance of MSW management systems particularly in rural areas. The management capability of local authorities can be enhanced with sophisticated facilities such as automated loading collection vehicle or mechanical sorting process. However, these technologies are often expensive or exceed local budgets particularly in developing areas. Many local authorities have aimed at full cycle integrated management system, but these have not been approved financially.

Lastly, a lack of public willingness to participate in the system and to pay fee for waste disposal has hindered the maximum efficiencies. Although the performance of local authorities has affected the willingness of the public to participate in the system, their own consciousness remains the key factor. Convenience plays an important role, as separating and bringing materials to exchange centers takes time and requires effort. Many residents separate their recyclable materials and wait for door-to-door scavengers to buy them. Thus, in the areas where scavengers are not available, source reduction is not encouraged.

According to the experiences of various countries, the deficiencies of existing MSW management systems in Thailand can be improved by providing the supports from national and regional governments, setting up the national goals and hierarchy as guidelines for all local authorities, passing laws to enforce both public and local authorities, providing more budgets, better facilities, and education, and improving the working structure of local authorities to support the planning and implementation activities.

This study has found that these measures have been implemented in Thailand in order to improve MSW management systems. The supports of central and regional authorities to assist local authorities in planning and implementing MSW services are now available. National goals are also set up for all local authorities with the provision of corresponding policies and guidelines to fulfill the goals. Regulations designating the role of all stakeholders in MSW management are also available.

More financial resources are available for local authorities such as the environmental fund. Better facilities are then developed and implemented.

With all these available resources, however, the site visit has found that many local authorities are still unable to achieve an efficient MSW management system. The problem is mainly due to the low management capabilities of local authorities in planning and maintaining the services. Many cases have shown that the financial and implementing problem is due to a poor planning. The increasing level of public awareness due to various campaigns has thus been hold back by the poor performance of local authorities.

Measures to enhance the planning capabilities of local authorities are required. The benefit cannot be maximized if local authorities are unable to improvise these supports. An improved planning capability will control and guide local authorities to carry out planning activities more systematically and prepare a more comprehensive management plan. MSW management plan will provide the right direction to the local authority to utilize available resources that meet local conditions and help the implementation team to regulate the management system more efficiently with a better control.

Other possible actions to enhance the management capability of local authorities are as follows. Regional authorities responsible for MSW management should be established to help local authorities in the region and to response to the establishment of regional treatment facilities. More details should be given to the issues of improving institutional structures, distributing appropriate technologies, and promoting public participation. The policy should focus on the provision of clear responsibilities to local staff, the development of a community-based technology, and the dissemination of information on MSW management system to the public.

2.4 PHILOSOPHY OF MSW SUSTAINABLE MANAGEMENT

Despite the record of solid waste management activities since 3000 B.C. (Tammemagi 1999), dealing with MSW was not of great concern until mid twentieth century. Before then, relatively insignificant amount was produced and the major components were biodegradable, so that the environment could assimilate the pollution naturally. Until human began to congregate in tribes, villages, and communities (1400s), large amount of waste was produced, led to the breeding of rats and flies (Tchobanoglous, Theisen and Vigil 1993).

Industrial revolution since 1800s with rapid development and population growth have exacerbated the situation when significant amount of MSW increased and more non-biodegradable materials were in the stream than ever. Thus, simple actions could no longer handle the waste without environmental impact. Consequently, "Age of Sanitation" began in England in 1842 (Tammemagi 1999) and in the United States in 1890s (Kollikkathara, Feng and Stern 2009). Land dumping was common method at early stage. Incineration was developed in mid 1890s in Europe followed by recycling in early 1900s (Tammemagi 1999).

Since then, the field of so called modern MSW management has been developed, which is defined by Tchobanoglous, Theisen and Vigil (1993) as ***the discipline associated with the control of waste from generation sources to disposal in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations, and that also is responsive to public attitudes.***

With regard to its sources, the major compositions of MSW are therefore food waste, paper, plastics, and glass. It can also include green waste, metal, aluminium, cloth, leather, wood, and ceramics. The composition of MSW varies from areas to areas, linked inextricably to the level of development of a country. Food waste is a largest content of MSW in developing countries while paper is a largest content of MSW in developed countries (Wilson 1981; Diaz et al. 2003). The general composition of MSW according to incomes is shown in Table 2-3.

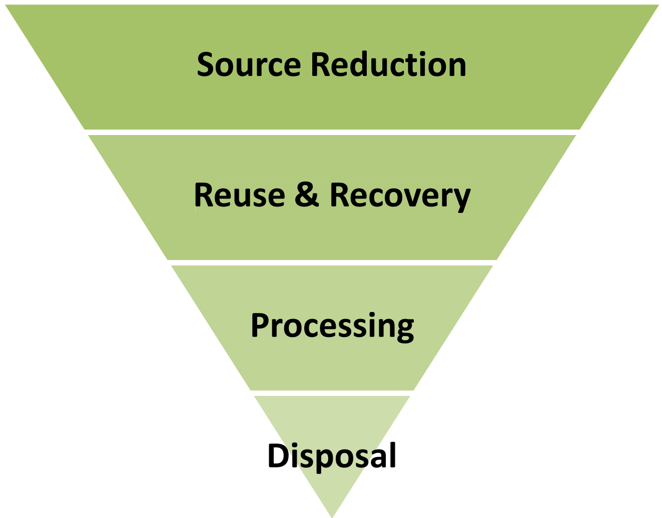
Table 2-3: Composition of MSW from different income regions

Regions	Physical Composition (%wet weight)						
	Organics	Paper	Plastic	Glass	Metals	Textiles	Other
Low income	41	5	4	2	1	-	47
Middle income	58	15	11	2	3	-	11
High income	28	36	9	7	8	-	12

Source: World Bank 1999

Fundamental objectives of MSW management to date are to remove the waste from habitats in a timely manner to prevent the spread of disease, to reduce aesthetic insults (Davis and Cornwell 1991), to divert or recover waste from the disposal site, and to reduce harmful impact before discharging. According to the objectives, effective MSW management system then refers to the system that is able to collect all waste, maximize reduction rate, and implement an environmentally sound waste treatment method for the remaining wastes.

To maximize the reduction rate, waste generation is prevented or minimised as much as possible at its source by redesigning production or changing patterns of consumption. Waste that cannot be prevented is then reused or recovered. This management concept is a so called ***waste management hierarchy***, which focuses on the prevention approach rather than the end-of-pipe approach. Source reduction is the first priority followed by waste recovery and waste treatment, with waste disposal as a last option only when other options are not feasible and all disposal methods must be environmentally sound as shown in Figure 2-3 (U.S. EPA 1999).



Source: adapted from US.EPA 1999

Figure 2-3: Waste Management Hierarchy

Once it has been accepted in general that only single measure cannot solve MSW problem. It needs the combination of various measures and technologies. The term ***integrated management system*** is then formulated. Following the concept of waste management hierarchy, integrated system should include optimised collection system, efficient sorting, proper treatments (material recycling, biological treatment, and thermal treatment), and sanitary land disposal. All activities must work together and cover all types of waste materials from all sources. As being interconnected, the entire system must be considered when designing or redesigning the system. General combination of MSW management activities at present are presented in Figure 2-4. Role of informal sector is more commonly found in developing countries than developed countries.

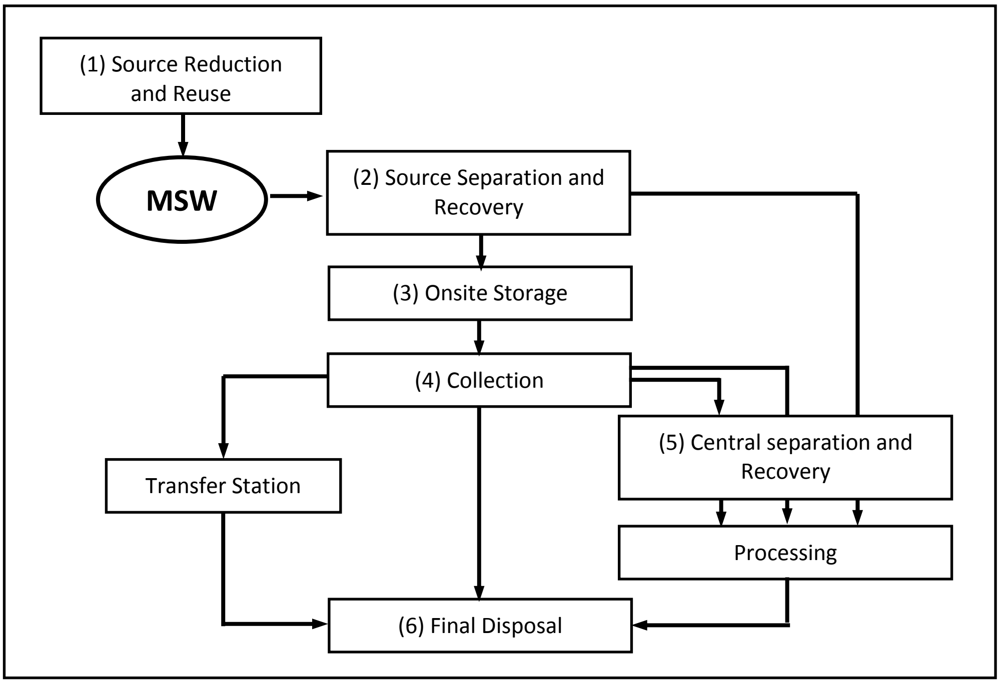
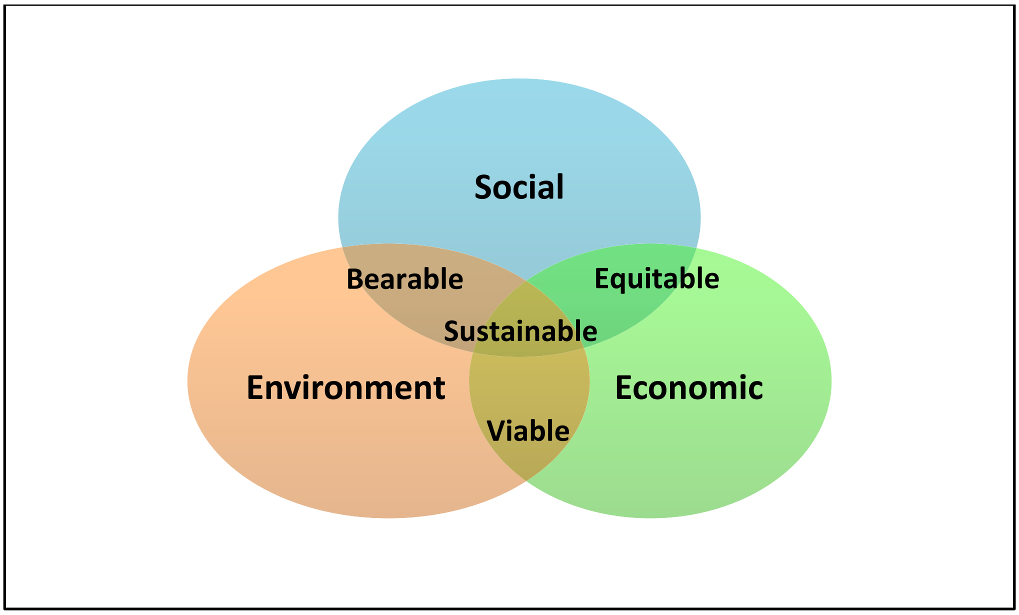


Figure 2-4: Structure of MSW management system in general

The performance of MSW management system is now framed by the concept of sustainable development. The idea started at the World Commission on Environment and Development (Brundtland Commission) in 1987 due to growing concern about the accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development.

However, the concept of sustainable development that is widely accepted at present was developed and declared at the 1992 Earth Summit in Rio as ***"that development that meets the needs of the present without compromising the ability of future generations to meet their own needs"***. Economic development is needed for improving well being of people in any countries. However, it is clear that the process exploits natural resources and generates residues that affect the quality of natural environment such as waste and pollution. These impacts, if not well controlled, will finally affect well being of people and the development of economic itself.

Therefore, natural resources and environment are used for the development of present generation but must also be preserved and protected for the development of next generation. Waste and pollution are managed in the way that does not pose any risk to human health or the environment, either now or in the future. Common picture to explain the concept of sustainable development is shown in Figure 2-5, where three components are related: economic, social and environment.



Source: adapted from IUCN 2006

Figure 2-5: General relationship for sustainable development

Sustainable development is achieved when three conditions are met – the middle area. Economics of all sectors in the society is equally developed. Budget is available for recovering the affected environment from such development back to an acceptable level. Social can accept the quality of surrounding environment affected and changed by the development.

Rio Declaration on Earth and Environment 1992 further develops an action plan for achieving sustainable development or so called "Agenda 21" addressing local changes that tie environmental protection to economic growth and human well being. Solid waste issue is included in Agenda 21 as being related to the development. The actions required to ensure that solid waste which is a direct consequence of the development is properly managed to reduce impacts on the environment for achieving sustainable development are addressed under Section II – Conservation and Management of Resources for Development including

(a) Minimizing wastes;

(b) Maximizing waste reuse and recycling;

(c) Promoting environmentally sound waste disposal and treatment; and

(d) Extending waste service coverage

In line with the sustainability concept, ***a common definition of sustainable MSW management is the system that should be environmentally effective, economically affordable, and socially acceptable*** (White 1998; Williams 1998; McDougall and Hruska 2000; McDougall et al. 2001). It refers to the system that reduces the environmental impacts of MSW from all parts of responsible area to the level that is accepted by the community in terms of operating manner and cost.

Moreover, the system should be flexible to adapt and operate in ways, which meet current social, economic, and environmental conditions, which are likely to change over time (McDougall et al. 2001). Tammemagi (1999) also recommended that sustainable waste management system should not pose a risk to human health or the environment either now or in the future; should not put any burden on future generation; or should conserve non-renewable resources such as land or recyclable materials.

2.5 CURRENT MEASURES AND TECHNOLOGIES FOR SUSTAINABLE MSW MANAGEMENT SYSTEM

Achieving sustainable MSW management is an ultimate goal of all countries nowadays. A number of measures and technologies have been developed. This section then reviews MSW management practices of both developed and developing countries which aim towards sustainable MSW management to reveal available choices for handling MSW at present. As explained in the previous section (Figure 2-4), the key activities associated with MSW currently are (1) source reduction, (2) source recovery, (3) onsite storage, (4) collection and transport/transfer, (5) processing and treatment, and (6) final disposal. Measures and technologies relevant to each activity are further presented.

2.5.1. SOURCE REDUCTION

Source reduction is the top of waste management hierarchy and the key activity for sustainable MSW management (Agenda 21). However, the activities are concerned and practiced in developed countries more than developing countries. Source reduction emphasizes not producing waste instead of managing waste. The amount of waste that is initially produced is reduced and then reducing environmental impact and the need for the use of disposal options downstream (Lober 1996). Source reduction can be implemented at both manufacturing industry and households.

Source reduction in industry is commonly known as *Waste Minimisation or Pollution Prevention* (Vesilind, Worrell and Reinhart 2002; Glavic and Lukman 2007). Thus, the term *source reduction* is usually applied to the household level (Lober 1996; Vesilind, Worrell and Reinhart 2002). Pollution Prevention or Waste minimization at source can be done by changing product, raw materials or technology (Williams 1998). ***Product*** particularly packaging can be changed to reduce weight and volume or to increase lifetime or be easier to repair in order to delay time to enter MSW stream (Lober 1996; Williams 1998; Tammemagi 1999; Taylor 2000; Henry, Yongsheng and Jun 2006; Glavic and Lukman 2007).

Input materials can be changed or substituted to reduce toxicity (Lober 1996; Williams 1998; Glavic and Lukman 2007) such as replacing organic solvents with water-based solvents or changing chromium plating material from Cr^{6+} to less toxic Cr^{3+}. ***Changing technology*** or known as Cleaner technology (CT) can also reduce waste (Vesilind, Worrell and Reinhart 2002). These can be changes in process conditions or change to an automated system, for example, changing cleaning circuit board sheeting process from chemical process to physical process, recycling cooling water or installing backwater tanks (Williams 1998). As can be seen, the benefit of waste minimisation is not only reducing cost of waste treatment but also cost of raw materials and energy.

At ***household level***, the amount of waste can be reduced only by changing the consumption pattern of residences (Franklin Associates, Ltd 1996; Tammemagi 1999; Taylor 2000; Damghani et al. 2008) such as purchasing products with minimal packaging, either in larger sizes or in bulk to minimise the number of containers or reusing these materials. This is a main reason why source reduction is practiced more in industry than household as it deals with technology rather than human attitude or behaviour which is more difficult and takes longer time to change. Other practices are such as refusing bags at stores, bringing one's own bags to grocery stores, buying goods without the outer box, using laundry detergent refills/ in a larger box, cloth diapers/ handkerchief and rechargeable batteries (Lober 1996).

To shift in attitude, there are three common approaches to enhance source reduction activities including (1) education, (2) incentives, and (3) forces. Education is a long term solution, which can be done through various way such as media e.g. brochures, T.V. announcement or meeting group. Importantly, the messages must create understanding on the reason for the need of source reduction - awareness on conserving limited natural resources and preventing litter and pollution

A common incentive for household to generate less waste is to charge collection fee according to the amount of waste they produce which could be either weight-base or volume based charge (Taylor 2000; Bai and Sutanto 2002; Lu et al. 2006; Kollikkathara, Feng and Stern 2009). Another option is prepaid bag system where only waste in designated bags is collected by collection agencies. This system is well established in U.S. (Taylor 2000) and Singapore (Bai and Sutanto 2002). The U.S. experience shows that it takes few years to be fully effective and has to carry out along with extensive educational programs and provision of options to reduce their waste to prevent illegal dumping.

Other way to enhance source reduction activities is on compulsory basis. Well known schemes are such as Polluter Pay Principle, Producer responsibility or Landfill Levy. However, Lober (1996) indicated that the public has low public awareness of source reduction comparing to recycling. Support for recycling was often greater than for source reduction. Therefore, the recognition that source reduction is more important than recycling must be increased through education.

2.5.2. SOURCE SEPARATION AND RECOVERY

Due to the fact that zero waste generation society is hardly achieved, generated waste thus must be recovered from the stream as much as possible to minimise the amount of waste requiring final disposal. In doing so, separation at source is a crucial activity. Wastes should be separated into different categories according to available treatment technologies. For example, dry waste/wet waste scheme is implemented when composting is available. Combustible waste/incombustible waste scheme is used when incinerator is dominated like in Japan. Other scheme is saleable/unsaleable waste when informal recycling or itinerant waste buyer is available particularly in developing countries.

Separation at household level will increase waste purity, reduce contamination and increase value of recovered materials particularly recyclables. The efficiency of MSW management system can be increased (Moghadam, Mokhtarani and Mokhtarani 2008). The efficiency of these downstream technologies thus largely depends on the purity or composition of incoming waste. For example, only organic component should enter composting facilities.

Single separation is commonly practiced where waste is separated into two streams such as dry and wet wastes or recyclable and non recyclable wastes. Multiple separations is also implemented where wastes are separated into three or four streams such as food waste, paper, plastics, metal and others or food waste, packaging, and others. This activity can be carried out either by householder or collection crews (curbside separation). Resident separates into wet and dry streams and collection crews further sort dry stream into different materials such as paper, plastics, glass, or metal.

Source separation can be either on voluntary basis or mandatory basis. Voluntary or informal separation often occurs in developing countries where formal separation or recycling is not in place and scavenger or itinerant waste buyers exist. Residents separate wastes and sell these materials particularly recyclables such as newspaper, magazines, cardboard and bottles to itinerant waste buyers. These recovered materials are sold through middlemen, dealers, or junk shop, who sort and pretreat the materials before selling to industries (Muttamara, Visvanathan and Alwis 1994; Wilson, Costas and Cheeseman 2006; Kofoworola 2006). Meanwhile, source separation is compulsory in various countries such as Japan, Germany, the United States or Taiwan. Residents are required by law to sort their waste into different categories.

2.5.3. SOURCE STORAGE

Generated waste needs proper containers at source due to public health and aesthetic concerns (Tchobanoglous, Theisen and Vigil 1993). The type and size of containers depends on at source handling activities, collection type, collection frequency, and location. Waste containers in house are usually plastic bag or plastic buckets. For communal storage, containers range from portable containers such as plastic bin with lid, oil drum or metal bin to fixed storage bin, enclosure or depot. However, portable plastic wheeled bin is the most common. Fixed storage is commonly used in developing countries such as in Indonesia (Pasang, Moore and Sitorus 2007); India (Hazra, and Goel 2008); Cameroon (Manga, Forton and Read

2008); Africa (Parrot, Sotamenou and Dia 2009); and other (Diaz et al. 2003; Shekdar 2009).

In developed countries, the appearance of container is modified recently. For example, the side of container for organic waste is perforated to allow air flow through the container for aerobic condition to reduce odour. Specific paper bag is also used to store waste in house before placing in the container at curbside. Moreover, two or four compartment bin is produced for collecting different materials in one bin. For apartment or multi stories building, centralized refuse chute is used (Tchobanoglous, Theisen and Vigil 1993; Bai, and Sutanto 2002; Jin et al. 2006). Waste is discharged directly from individual flats through discharge chute to bulk container stored on the basement of the apartments.

In commercial area, different colour containers are commonly used for different materials. However, waste is placed in the container from the front side rather than the top with different shape of input holes according to the shape of waste materials. Contaminant can be reduced. The dumpster-type container is another option to separate recyclable materials. The dumpster is collected by automated dumpster loaders, which is mechanically lifted and either dumped into the vehicle or placed on the transport vehicle (Diaz et al. 1993).

2.5.4. COLLECTION AND TRANSPORTATION

Purpose of collection process is to ensure that all waste is removed from community in a timely manner (Tchobanoglous, Theisen and Vigil 1993). At present, various collection systems have been developed to suit characteristics of service areas. However, it can be classified into two main categories: (1) collection trucks collect waste from the front of houses or apartment and (2) residents are asked to bring their waste to fixed station for collection. The former system includes curbside collection and door to door collection. The latter includes drop off collection, communal collection, depot, block collection

In developed countries, ***curbside collection*** is commonly practiced. In general, for this system, residents place their containers to be emptied at the curb on the collection and return back to storage location until the next collection day (Tchobanoglous, Theisen and Vigil 1993; Agunwamba, Ukpai and Onyebuenyi 1998; Diaz et al. 2003; Turan et al. 2009; Kollikkathara, Feng and Stern 2009). Another collection system is so called ***door to door collection*** in which the collector enters the premises carries the container to vehicle, empties it and returns to its usual place (Diaz et al. 2003). Homeowner is not involved in collection process. This system is also used in other terms such as ***back yard collection*** (Vesilind, Worrell and Reinhart 2002) or ***set out/set back system*** (Agunwamba, Ukpai and Onyebuenyi 1998).

However, door to door or house to house collection system implemented in developing countries refers to a different system. The system requires residents to bring out their waste and load directly to the truck when truck horn or bell is ringing (Kum, Sharp and Harnpornchai 2005; Pasang, Moore and Sitorus 2007; Manga, Forton and Read 2008; Hazra and Goel 2008; Shekdar 2009). But irregular service due to high break down rate forces resident to leave their waste at the curb or roadside for collection. To solve this problem, the system is changed by placing public portable containers at the curb at all times and resident can bring their waste from home to container at the curb whenever they want.

Communal collection is the system in which large communal bin or masonry enclosures or small concrete bin is sited in designated location (Diaz et al. 2003; Hazra and Goel 2008) and residents are required to bring their waste to the location. Small cart may be needed when participation is low to collect waste from other points. This collection system is also called as fixed point collection (Agunwamba, Ukpai and Onyebuenyi 1998; Pasang, Moore and Sitorus 2007; Manga, Forton and Read 2008; Shekdar 2009) or Alley system (Agunwamba, Ukpai and Onyebuenyi 1998). Another system is block system operated in Latin America (Diaz et al. 2003) and Africa (Korfmacher 1997). Collection vehicle stops at street intersections and ring the bell. Residents then bring their containers to be emptied by collection crews.

The system is also termed as Drop off collection in U.S. (Kollikkathara, Feng and Stern 2009), or Bring system in U.K. (Williams 1998) when formal recycling program is implemented. Residents are required to bring their source separated materials to large communal bin only for recyclable materials situated at local supermarket. Another advanced collection system for apartment or multi stories building is Pneumatic refuse collection (Tchobanoglous, Theisen and Vigil 1993; Bai and Sutanto 2002). Waste discharged through chutes and stored on the basement of a cluster of apartment is sucked through underground pipe either to collection truck or a central station.

The type of collection vehicles varies upon the type of collection system. Compactor truck (10-20 m^3 capacity) is commonly used in urban areas where the density of waste is low (100-170 kg/m^3) in which compactor truck can increase the volume of MSW collected per trip. This is a reason why compactor trucks should not be used in developing countries or rural areas where their MSW is denser (250-500 kg/m^3) (Korfmacher 1997). It can be rear loading, side loading or front loading. Automatic loading system is commonly used in developed countries. Typical collection vehicles with manual loading used in developing countries are side loading trucks (10-15 m^3 capacity), and pick-up trucks (3-4 m^3 capacity). Special container transport trucks (6-7 m^3 capacity) are used for hauled container systems (Thongnark 1997).

A transfer station is introduced when direct hauling to a disposal site or a processing plant is no longer economically viable (Tchobanoglous, Theisen and Eliassen 1977). The transfer station is where MSW are transferred from small vehicles to larger trucks and compacted to high density. A major advantage is the reduction in waste transportation costs by decreasing the number of vehicles travelling to disposal sites (Tchobanoglous, Theisen and Eliassen 1977).

The waste is transferred either directly to the larger vehicle or to storage pit before loading to another vehicle. For direct loading, two levels arrangement is required and it is implemented as a small-scale system (Vesilind, Worrell and Reinhart 2002; Moghadam, Mokhtarani and Mokhtarani 2008). Waste is discharged into opentop trailer (Moghadam, Mokhtarani and Mokhtarani 2008). For storage loading system, three levels arrangement is common. Collected waste is temporally stored in holding facilities on second floor, having trap door through the ceiling of the first floor. Truck enters the first floor and ceiling is opened. MSW is automatically dumped into the truck (Hui et al. 2006).

2.5.5. PROCESSING AND TRANSFORMATION

The objective of waste processing is to reduce the volume or environmental harm before final disposal. MSW is now seen as valuable resources to replace virgin materials or non renewable energy. At present, a number of MSW processing methods have been developed according to waste properties to recover its value. Based on the experiences of various countries, waste treatment technologies that are commonly implemented are recycling, composting, and combustion. Recently developed technologies are pyrolysis, refuse derived fuel (RDF), gasification and anaerobic digestion. However, only the detail of well established technologies is further described.

2.5.5.1. MATERIAL RECOVERY FACILITIES

Material recovery facility (MRFs) is important component particularly for recycling business. MRFs is a place where valuable materials are removed from the waste stream going to Landfill and mixed recyclable materials or dry wastes are systematically sorted into individual streams, cleaned, and baled before delivery to recycling industries. This improves the purity and quality of any recycled product. Contamination basically means wet waste or non recyclable wastes.

Thus, the efficiency of MRFs largely depends on the performance of source separation program. If wet waste is well separated at source, the purity of recovered materials can be very high. For example, 90% of source separated materials would be recovered compared to only 15% of mixed waste which is considered as a high contaminated waste (Williams 1998). However, MRFs is more common in developed countries than in developing countries.

Types of incoming wastes can be mixed waste, commingle waste or source separated waste. The facility commonly consists of waste receiving area, processing area, and storage area. The recommended size of each component is given in Table 2-4.

Table 2-4: Recommended size of Material Recovery Facilities

Area Use	**Facility Capacity (Tonnes/Week)**		
	10	**100**	**500**
Tipping floor (m^2) 2-day capacity	300	750	3,000
Processing (m^2)	600	2,000	5,000
Storage (m^2) 7-day capacity 14-day capacity	100 175	875 1,750	3,500 7,000

Source: Diaz et.al. 2003

The typical MRFs can recover ferrous metal, plastics, aluminium, glass and several grades of paper. The finished product of MRFs is used in secondary processing such as recycling and composting. The facility can be either manual or mechanical processes. Basic equipments are conveyor, elevator, shredding, and compactor or baler. In developing countries, informal recovery group can operate the simple facility to enhance the quality of their recovered materials. Separation can be simple and manually intensive process with minimal support of mechanic equipments such as sorting belt (Diaz et al. 2003) or baler to enhance their performance. Debagger may be important when waste is usually stored in plastic bag before placing in container. General manually sorting rate is given in Table 2-5.

Table 2-5: Manually sorting rate at Material Recovery Facilities

Material	Sorting rate (kg/hr/sorter)	Recovery Efficiency (%)
Newspaper	700-4,500	60-95
Corrugated	700-4,500	60-95
Glass containers (mixed color)	400-800	70-95
Glass containers (by color)	200-400	80-95
Plastics containers	140-280	80-95
Aluminum cans	45-55	80-95

Source: Diaz et.al. 2003

In developed countries, separation can be mechanical intensive process when labour cost is expensive. Incoming waste can be separated based on the difference of size by screening (vibrating screen, trammel screen, or disc screen) commonly for separating glasses from other materials. The difference of density or aerodynamic characteristics such as air classifier is used to separate papers and plastics (Tchobanoglous, Theisen and Vigil 1993; Diaz et al. 2003). Magnetic separator and eddy current separator is further used to separate metal and aluminium respectively. In 1995, there were 310 MRFs in the U.S., of which 114 MRFs used high technology such as trommel screening, eddy currents, magnetic separation, optical sensors, and air classifiers (Franklin Associates, Ltd. 1996).

With the increase of environmental concern and the development of separation technologies, recycling rate is increasing in most of the countries. However, recycling rate of each material varies, based on the industries in each country. For example, recycling rate in Portugal are 12.5% for paper/cardboard, 4.5% for plastics, 30.2% for glass, 24.2% for steel and 6.9% for aluminium (Magrinho, Didelet and Semiao 2006). Glass has a highest rate. While, recycling rates in China are 20% for paper/cardboard, 25% for plastics, 85% for steel and 80% for aluminium (Shekdar 2009) with 13% for glass, the lowest.

2.5.5.2. COMPOSTING

Composting is a common method for reducing organic waste from MSW stream by converting this waste into a usable soil fertilizer (Horan 1999). Aerobic decomposition process is taken place as (Tchobanoglous, Theisen and Vigil 1993):

$$\text{Organic waste} + O_2 + \text{Nutrients} \xrightarrow{\text{Aerobic bacteria},\ H_2O} CO_2 + H_2O + NO_3^- + SO_4^{2-} + \text{Compost} + \text{Heat}$$

The efficiency of the process depends on various factors including pH, temperature, moisture content, C/N ratio, and air flow rate. Although organic waste is the largest or second largest portion of MSW in which composting should be the best treatment option, its implementation is limited by the level of contamination and high operating and maintenance cost (Hui et al. 2006; Magrinho, Didelet and Semiao 2006; Narayana 2009; Nguyen and Schnitzer 2009).

The contaminants such as heavy metals, glass or other inert materials, have adverse effects on germination and growth of plants, when the compost is used as a fertilizer. To address this problem, many countries have started backyard composting programs to avoid contamination, where organic waste is composted before mixing with other materials (Franklin Associates, Ltd 1996). New uses of the compost, which can make composting more attractive in the market (Horan 1999) are being investigated.

Various countries have improved on their composting technology to increase the quality of the compost. Optimal conditions have been widely investigated to achieve high efficient composting technology, for example, aeration rate (Bari and Koenig 2001; Rasapoor et al. 2009), moisture content (Bueno et al. 2008), or temperature (Elango et al. 2009).

2.5.5.3. INCINERATION

Combustion is a thermal processing to convert solid waste into gases, liquid, and solid, with the subsequent release of heat energy (Tchobanoglous, Theisen and Vigil 1993). The advantages of combustion process are maximum volume or weight reduction, organic fraction stabilisation, and energy recovery. Thermal treatment system can be classified into three types according to the quantity of supplied air into the combustion process including incineration, gasification, and pyrolysis. However, a common type of thermal treatment for MSW at present is incineration. Excess air is provided for incineration to obtain complete combustion.

The combustion chamber can be stoker or fluidize bed system. The volume reduction of conventional MSW incinerator ranges from 85% to 95% (Tammemagi 1999). Sophisticated pollution control facilities can help to maintain or even improve environmental quality. Waste-To-Energy (WTE) plants help to convert collected MSW into steam and electricity that can be sold to electricity generating utilities. Most modern incinerator facilities are designed with the capacity to recover energy inherent in the residual waste, supplementing fossil fuel system. All German MSW incineration plants implemented boiler in order to utilize the energy (Vehlow 1996). MSW incineration in the U.S. is also commonly conducted in WTE plants.

However, the concern of air emission has resisted in the implementation of incineration at present even in Europe or Japan (Narayana 2009). General air pollutants from incinerator are particulate matter, CO_2, NO_x, SO_x, HCl, Heavy metal, Dioxin (Polychlorinated dibenzo-p-dioxin) and Furans (Polychlorinated dibenzo-furans). Dioxin and furans are carcinogen substance. Ash is another by product of combustion process which is disposed of in landfill. Leaching into soil and groundwater is critically concerned.

Various air pollution control technologies have then been developed such as bag filters, gas scrubbers and electrostatic precipitation (Bai and Sutanto 2002). Dioxin/ Furan can be suppressed by achieving complete combustion, lowering the inlet temperature at the dust collector, and installing electrostatic precipitator or fabric filter (Sakai 1996). The efficiency of air pollution control technologies is summarised in Table 2-6. Generic treatment technologies for ash are solidification, chemical stabilization, ash melting, and recovery process (Sakai 1996; Sakai et al. 1996).

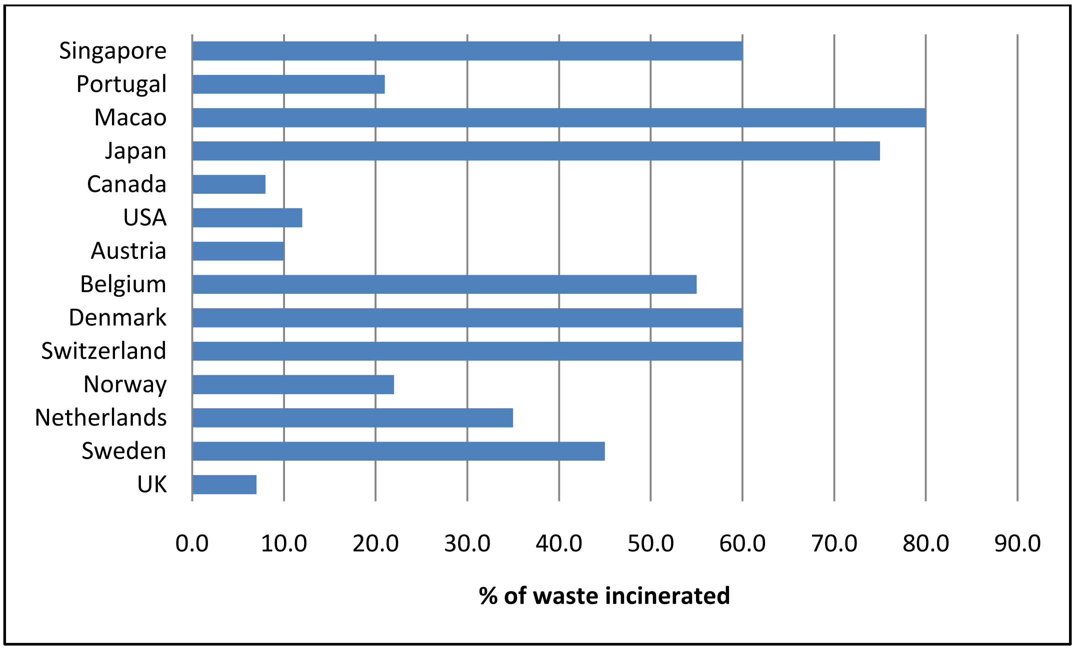
Table 2-6: Efficiency of Air pollution treatment technologies of MSW incineration

Treatment Technologies	Air Pollutants	Treatment Efficiency
Fabric Filters (Bag House)	Particulate matter	95 – 99%
Electrostatic Precipitator (ESP)	Particulate matter	95 – 99%
Ammonia injection	NO_x	10 - 60%
Wet scrubber - $Ca(OH)_2$	SO_2	50 – 85%
Wet scrubber - $Ca(OH)_2$	HCl	75 – 90%
Dry scrubber - Na_2CO_3, $Ca(OH)_2$	SO_2	50 – 85%
Dry scrubber - Na_2CO_3, $Ca(OH)_2$	HCl	75 – 90%

Source: Diaz et.al. 2003

Despite well developed technology, waste combustion is mainly implemented in developed countries particularly in Europe. Incineration is not recommended for MSW in developing countries because the calorific values of incoming waste is low, capital and operating cost of thermal treatment is much higher than other treatment methods, and maintaining operating conditions is difficult (Williams 1998; Narayana 2009; Shekdar 2009; Nguyen and Schnitzer 2009). Comparison of

MSW incineration in various countries is illustrated in Figure 2-6. As can be seen, incineration is common in countries with small geographical area such as Scandinavian, Japan, Macao, and Singapore.



Source: Seik 1997; Williams 1998; Jin et al. 2006; Magrinho, Didelet and Semiao 2006

Figure 2-6: Comparison of MSW incineration in various countries

2.5.6. FINAL DISPOSAL

Even with the maximum efficiency of recovery and treatment systems, landfill is still required for the disposal of residues from treatment facilities. Thus, landfill is expected to remain a major method in MSW management in the future (Franklin Associates, Ltd 1996). Land disposal being used at present can be classified into three types: open dumping or landfill, controlled landfill, and sanitary landfill.

In developing countries, open dumping in which waste is simply dumped into low laying areas of open land and controlled landfill in which waste is compacted and covered daily are common practice. As a result, surface and groundwater contamination is often observed. Meanwhile, sanitary landfill is implemented in developed countries in which the facility is designed and operated to minimise public health and environmental impacts.

Modern landfill includes (1) compacted clay or impermeable materials such as plastic liner, (2) leachate collection and treatment systems, (3) surface water drainage system, (4) groundwater monitoring wells, (5) daily cover, (6) gas monitoring and controlling system, (7) venting systems after landfill is sealed off, and (8) compacted clay or composite layers on the top as a final cap, when landfill has reached its filling capacity.

Impermeable liners such as compacted clay or geotextiles are used at sanitary landfill sites to prevent leachate leakage from contaminating groundwater. The liner system can be single liner (only a layer of compacted clay or HDPE), double liners (two layers of compacted clay or HDPE), and composite liners (compacted clay with HDPE). Sand layer should be above the liners as leachate drainage system where generated leachate is collected and conveyed to the surface for treatment before discharged.

Basically, the quality of leachate varies with time. The early stage of landfill (few years after closure), leachate has a high organic content in terms of BOD and COD. With time, the concentration of contaminants decreases and reaches stable stage. Leachate treatment is such as aerated lagoon where sufficient land area is available. Activated sludge system can remove 90-99% of BOD and COD and 80-99% of heavy metals (Qasim and Chiang 1994). This system also requires only a small area compared to the aerated lagoon. Once the organic content decreases, the physico-chemical treatment such as coagulation-precipitation, sand filter or activated carbon is added to remove colour, suspended solid, heavy metals and total coliform (Carra and Cossu 1990).

Rainwater diversion and drainage system is installed to reduce leachate production. Diversion ditches should be installed along the periphery of sites to collect upland run-off. Also, collection and drainage systems should be constructed to limit runoff within the site areas (Ehrig 1984). Daily cover is implemented to decreases leachate and release of green house gases to the atmosphere.

Gas collection system is installed to capture and flare or to generate electricity. Basically, two common landfill gas collection methods are the passive system and the active system. In the passive system, the movement of gases depends on a natural pressure. Sandy soil and gravel are used for a final cap to allow the migration of gas, when pipes and venting are not installed. In the active system, gas is driven by a vacuum (created by compressor or blower) through extraction wells. Groundwater monitoring wells are used to test the quality of surrounding groundwater and to trace unexpected leakage.

At present, many research projects are focusing on various aspects of landfill design and operation, for example, co-disposal of ash, toxic waste or liquid waste with domestic waste to improve the quality of landfill leachate, or leachate recirculation to enhance the stabilization of landfill. In addition, there are growing research on liner technology, quality assurance during installation, on-site landfill leachate treatment, and methods to increase landfill gas production.

2.6 FACTORS FOR SUSTAINABLE MSW MANAGEMENT SYSTEM

This section reviews MSW management in other countries, apart from Thailand. Experiences of these countries were used to set up suitable management scheme for MSW management Thailand. From the literature survey, country reports on MSW management systems of 32 countries, both developed and developing countries from all five continents, were reviewed to identify factors influencing the performance of their MSW management systems. European countries are Denmark (Sakai et al. 1996; Veltza 1999), Germany (Vehlow 1996; Sakai et al. 1996), Greece (Agapitidis and Frantzis 1998), Portugal (Magrinho, Didelet and Semiao 2006), Poland (Grodzinska-Jurczak 2001), Sweden (Sakai et al. 1996; Vencatasawny, Ohman and Branstorm 2000), The Netherlands (Sakai et al. 1996; van der Sloot 1996), Turkey (Turan et al. 2009), and The United Kingdom (William 2003).

Asian countries are Cambodia (Kum, Sharp and Harnpornchai 2005; Parizeau, Maclaren and Chanthy 2006), China (Hui et al. 2006), Japan (Sakai 1996; Sakai et al. 1996), India (Rathi 2006; Srivastava et al. 2005; Narayana 2009; Hazra and Goel 2008), Indonesia (Pasang, Moore and Sitorus 2007; Supriyadi, Kriwoken and Birley 2000), Iran (Moghadam, Mokhtarani and Mokhtarani 2008), Israel (Nissim, Shohat and Inbar 2005), Macao (Jin et al. 2006), Nepal (Pokhrel and Viraraghavan 2005), Palestine (Al-Khatib et al. 2007), Singapore (Seik 1997; Bai and Sutanto 2002), Sri Lanka (Vidanaarachchi, Yuen and Pilapitiya 2006), Taiwan (Lu et al. 2006), and Tehran (Damghani et al. 2008).

African countries are Cameroon (Manga, Forton and Read 2008; Parrot, Sotamenou and Dia 2009), Kenya (Henry, Yongsheng and Jun 2006), Nigeria (Agunwamba 1998; Agunwamba, Ukpai and Onyebuenyi 1998; Kofoworola 2006), South Africa (Korfmacher 1997), and Tanzania (Yhdego 1995). MSW management of Australia (The Aditor-General 2000), New Zealand (Boyle 2000), Canada (Sawell, Hetherington and Chandler 1996; Sakai et al. 1996), and The United States (Sakai et al. 1996; Taylor 2000; Kollikkathara, Feng and Stern 2009) were also reviewed.

Based on the experiences of these countries, five common factors were addressed when the successes or failures of MSW management systems were concerned. These factors are:

(1) the capability of management organisation,

(2) policies and plans,

(3) legislation,

(4) budget, and

(5) public participation

Interestingly, the capability of management organization or local authorities was mentioned in all those 40 papers as a factor for effective MSW management. The availability of budget was the second factor frequently mentioned, followed by policy and plan, regulation, and public participation as summarised in Table 2-7.

Table 2-7: Proportion of studied papers referring to each factor on the performance of MSW management

Factors	% of studied papers
Management organization	100%
Budget and funding	93%
Policies and plans	86%
Legislation	79%
Public participation	62%

Their experiences illustrates that properly arranged management organization with sufficient financial resources are fundamental requirement for starting up effective MSW management. Moving toward sustainable MSW management further needs local authorities to develop appropriate strategies, policies, and regulation and to encourage the public (community, information sector, industries) to participate in the system via education, incentives, or forces. The relationship of these factors is summarised in Figure 2-7. The details of each factor are described.

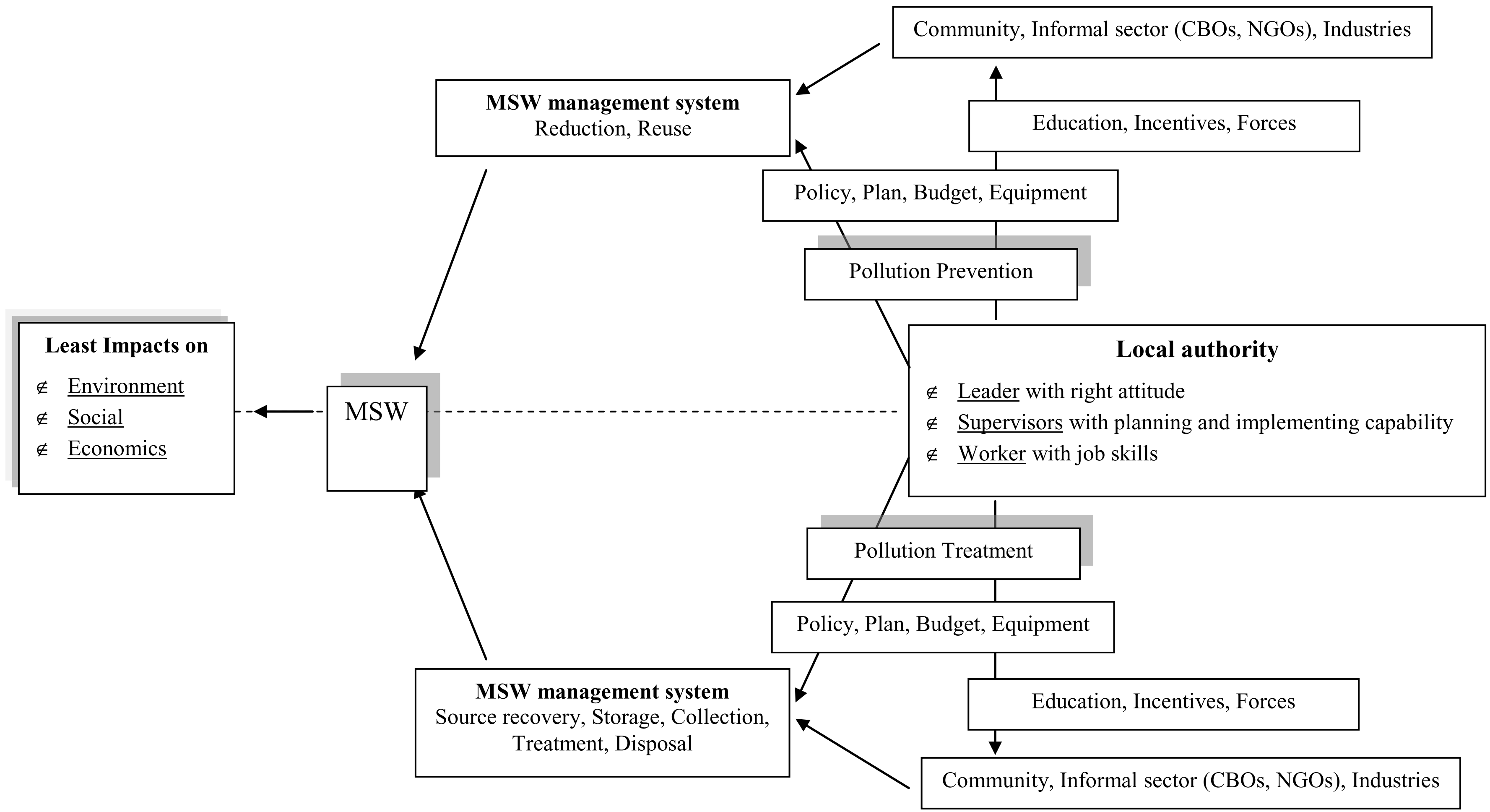


Figure 2-7: Structure for an effective MSW management system

Unfortunately, the above conditions rarely exist in developing countries. Management organisation is usually weak. Comprehensive policy and legislation is not available. Budget and facilities are inadequate. Consequently, public relations and participation are poor. Effective MSW management systems are thus rarely available in developing countries. Although attention should be paid to all these five key factors simultaneously in order to enhance the performance of MSW management system due to their interrelation, building the capability of local authority should be the first priority. This statement is supported by Diaz, the Editor in Chief of Waste management journal (Diaz 2009).

2.6.1. THE MANAGEMENT CAPABILITY OF LOCAL AUTHORITIES

Achieving a sustainable MSW management system firstly requires effective management organization to develop comprehensive policies and plans, enact and enforce legislation, acquire resources, implement and regulate management system, and encourage the public to participate in the system. These are common responsibilities of local authority at present. Thus, the performance of the local authority directly influences the level of public participation, which significantly contributes to the success of the program (Korfmacher 1997).

In various countries, particularly developed countries, other governmental levels (central and regional governments) are involved in MSW management services to ensure that local authorities can fulfill these conditions (Bonomo and Higginson 1988; van der Sloot 1996). The roles of each governmental level in MSW management of some countries are given in Table 2-8.

In general, central government establishes national goals, policies and strategies as a guideline for local authority to ensure that all local authorities design its MSW management system in the direction that will meet the national goals. Standards, criteria, and regulations are also developed as control measures. Central government may also provide technical and financial assistance to a local authority for developing and regulating the management system.

Table 2-8: The role of governmental body in MSW management

Country	Responsibility		
	National Government	**Regional Government**	**Local Government**
Canada[(1)]	Provides information; exchange and support services	Sets up policies; monitors operations; gives approvals and incentives to implement policy	Delivers service including the plan, design, site applications and operations
Denmark[(1)]	Grants operating permission; exerts control over municipalities	Grants operating permission; exerts control over private enterprises	Collects household waste and regulate landfill
Japan[(1)]	Establishes standards for controlling and evaluating the pollution; develops and promotes technologies; gives technical and financial assistance to municipalities/prefectures	Provides necessary technological assistance and measures for adequate waste disposal to municipalities	Sets programme for the management of domestic wastes in the respective area
Switzerland[(1)]	Lays down basic laws and relative ordinance and directives	Supervises town council	Collects and disposes of waste and consult with the private companies if contracted
United Kingdom[(1)]		Enacts legislation governing the management of wastes; publish guidance; sponsors research into waste management; inspect waste facilities	Applies control mechanisms defined by law; collects and disposes of waste
United States of America[(1)]	Establishes objectives, guidelines for implementation of state plans, and criteria for the proper disposal practices	Implements and enforces the national criteria through state regulation and a permit process	Manages collection and disposal of MSW to ensure protection of public health and the environment
Australia[(2)]	Fosters co-operation between itself and the States and Territories; develops nationally consistent standards and measures in environmental management	Legislates responsibility to encourage coordination; carries out long-range planning; approves regional waste management plans; licenses landfill sites and oversees the collection of landfill levies	Provides curbside and public collection, recycling, treatment, and disposal services

Source: (1) Bonomo and Higginson 1988; (2) The Aditor-General 2000

Some cases, regional authorities transfer the national obligations and assistance to the local level. A regional authority adopts the national goals, policies, criteria or standards to suit its own region and makes national law more stringent for the region (Carra 1990). Regional authorities also educate and supervise local authorities in preparing management plan and developing MSW management technologies. Regional authorities may also assist local authorities in operating shared facilities in the region. Based on the review, the relationship of each governmental level is summarised in Figure 2-8.

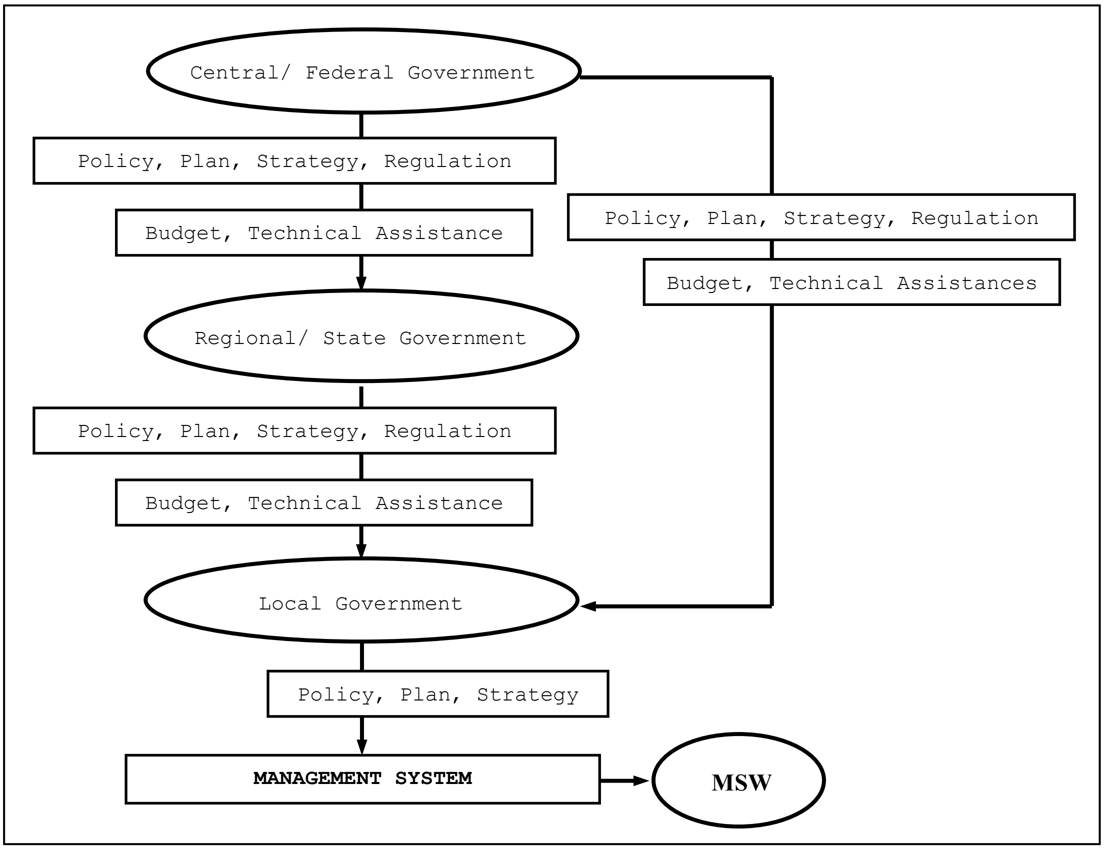


Figure 2-8: Common governmental structure for MSW management

Figure 2-8 also shows that the performance of local authority is crucial to the success of MSW management as being closest to the management system. In responding to its duties, local authority must efficiently perform two key functions; planning and implementation. It is recommended that a specific unit for each function should be established but must be working together (Bartone 1991). The connection of these two functions is presented in Figure 2-9. An effective MSW management system thus requires both skillful planners and operators.

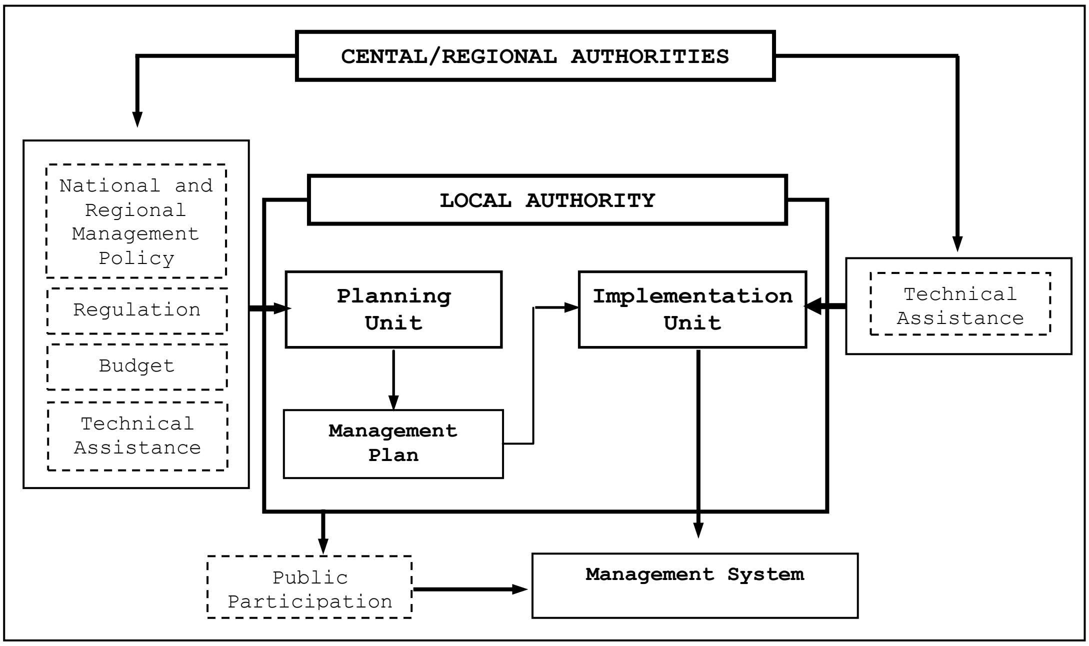


Figure 2-9: Structure of a local authority for MSW management system

Figure 2-9 shows that the planning unit develops MSW management plan for the implementation unit. A planning unit establishes goals or policies, designs actions, and allocates resources that will enable the organisation to best cope with existing conditions. The planning unit needs to analyse all available management choices from national and regional management policies or private consultancies and decides the best management actions under existing circumstances. The outcome of the planning unit is policy, strategy, or operational plan, which provides a working framework for the implementation unit.

Waste management plan is an essential requirement for improving waste management practices (Ball 1999). Flinoff (1984) recommended that a workable waste management plan needs to be developed for each region. Ideas, equipment, or advice from other regions or countries may be useful but not entirely satisfactory (Rushbrook and Finnecy 1988). Therefore, each local authority needs an effective MSW management planning system in its organisation to prepare the MSW management plan for its region.

The implementation unit is responsible for bringing the developed plan into effect. Implementation actions include organising, directing, and controlling (Cleland and King 1983). Personnel and facilities suitable for the tasks are organised, based on their ability and capacity. All available resources are then put in place and directed according to the management plan to perform collection, recovery and disposal services to achieve the objectives. Implemented MSW management system is then controlled according to the management plan. Control action determines what remains to be done and applies any necessary corrective action. The assessment information is subsequently used in the next planning cycle.

According to its relationship, the performance of the implementation unit relies partly on the performance of planning unit. Thus, having an effective MSW management the planning unit will also enhance the performance of the MSW management system. The problem of inadequate budgets or low public participation can be eased by a good MSW management plan. Collection and transportation cost, accounting for a half of the entire management cost, can be significantly reduced while the efficiency increases if properly planed. Improved performance of the local authority will slowly but eventually gain backs the public's confidence and willingness to participate.

However, the planning issue is of less concerned when compared to the operating issue. Current research related to MSW management planning systems of local authorities is limited. Moreover, this issue is of less concerned in developing countries. Political pluralism is another crucial key for the success of either planning according to actual conditions or implementing system according to the scientific plan (Henry, Yongsheng and Jun 2006).

2.6.2. BUDGET

The availability of financial resources is the second frequently criticized factor, when the performance of MSW management system is concerned particularly in developing countries. In general, MSW management consumes between 20 and 50% of the available operational budget of the municipal services (Arlosoroff 1991). Many local authorities in developing countries spend over 30% of their budgets on waste collection and disposal (Henry, Yongsheng and Jun 2006).

Capital budget for MSW management commonly comes from national expenditure, environmental fund, or grants from central authorities. Local authority revenue is then covering operating costs. The operating cost is fundamentally drawn from service fee and tax collection, and properties and enterprises and loans (UNESCAP 2002). The structure of local authority revenues is shown in Figure 2-10.

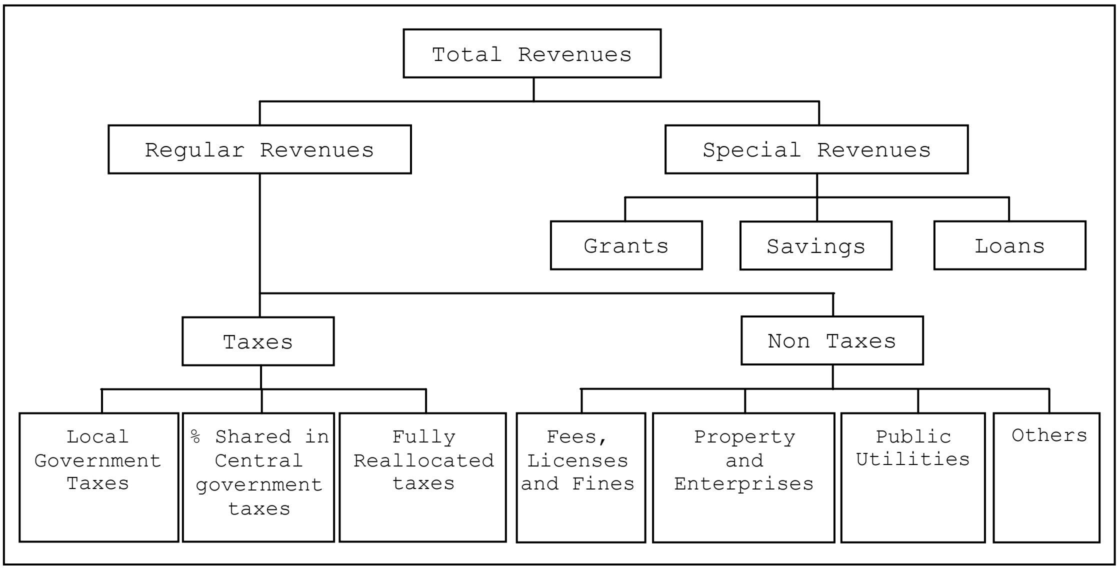


Figure 2-10: Revenue structure of local authorities in developing countries

Cost associated with MSW management system can be divided into three categories including capital cost, labour cost and operating and maintenance cost. Based on the cost data of waste activities by UNEP 1996 (Massoud, El-Fadel and

Malak 2003), the proportion of capital and labour cost of all activities is equal and slightly higher than operating and maintenance cost. Of this budget, collection services including cleansing could account for 80% - 90% (Gupta et al. 1998; Massoud, El-Fadel and Malak 2003) as shown in Table 2-9. This is a similar trend in both developing and developed countries. It is no doubt why MSW management cost in developed countries is much higher than developing or low and middle income countries as advanced technologies are normally utilized such as compactor trucks or incinerator with sophisticated pollution treatment system.

Table 2-9: Comparison of waste service cost

	Low income countries	**Middle income countries**	**High income countries**
Total cost/ton (US$/yr)	**48 - 95**	**95 - 225**	**240 - 430**
Collection	15 – 30	30 – 70	70 – 120
Cleansing	30 – 60	60 – 140	140 – 240
Transfer	3 – 5	5 – 15	15 – 20
Disposal	1 – 3	3 – 10	15– 50

Source: Massoud, El-Fadel and Malak 2003 based on UNEP 1996

However, if compared with the average income, the cost of MSW management services in developed countries is much lower than in developing countries. As shown in Table 2-10, MSW management cost accounts only for 0.7% of their income compared to 2.5% in developing countries. This clearly shows the reason why local level in developed countries can afford more sophisticated system. Large budgets are essential for investing in technologies and facilities of MSW management system. This is an important barrier for developing countries, where national income is low.

Table 2-10: Comparison of MSW services cost and residential income

	Low income countries		Middle income countries		High income countries	
	Cost/cap (US$/yr)	% of aver. income	Cost/cap(US$/yr)	% of aver. income	Cost/cap (US$/yr)	% of aver. income
Total cost	**4.4 - 8.8**	**1.35–2.5**	**12.3 - 29.7**	**0.75-1.7**	**64.2-139.2**	**0.32-0.71**
Collection	3 - 6	0.9-1.7	9 - 21	0.5-1.1	42 - 72	0.2-0.4
Cleansing	0.6 - 1.2	0.2-0.3	1.8 - 4.2	0.1-0.2	4.2 - 7.2	0.02-0.04
Transfer	0.6 - 1.0	0.2-0.3	1.5 - 4.5	0.1-0.2	9.0 - 30.0	0.05-0.07
Disposal	0.2 - 0.6	0.05-0.2	0.9 – 3.3	0.05-0.2	9.0 – 30.0	0.05-0.2

Source: Massoud, El-Fadel and Malak 2003 based on UNEP 1996

To address this problem, the private sector can be involved to provide management to address the financial problem (Agunwamba 1998). In addition, economic incentive should be available to reduce waste. The cost of environmental damage associated with solid waste disposal is incorporated into the prices of goods and services (Agunwamba 1998). Financial tools can also be available in form of duties/charges and subsidy schemes (Veltaza 1999). Charges should be made for waste collection to ensure that the total revenues cover the operating cost in order to sustain a successful waste management program.

There is another scheme to solve financial problem, for example in Taiwan (Lu et al. 2006). The extended producer responsibility program (EPR) is adopted for their recycling program where manufacturers and importers must pay the recycling fee into a recycling fund, managed by the Recycling Fund Management Board. The Taiwan Environmental Protection Administration (TEPA) also involved in recycling activities and used its recycling fund to subsidize the recycling activities of local government for example to buy recycling trucks for specifically collecting recyclable waste. Public is required to bring its recyclable waste to collection crews. Collection crews are mandated to sort 12 waste items. The earning is then used to reward these crews and communities.

2.6.3. POLICY AND PLAN

A management policy and plan providing a right and clear direction to achieve a sustainable MSW management system is essential to ensure a long term success. As mentioned earlier, the objective of sustainable MSW management to date is to minimise waste generation and going to final disposal Waste must be handled in an environmental friendly manner. The United Nation Environment Programme and World Health Organisation (Rushbrook and Finnecy 1988) have jointly set out the policy for the structure of MSW management system to achieve such objectives as follows.

Processes and activities producing the minimal waste and hazard should be chosen. All feasible and reasonable steps to reclaim materials from the waste should be taken. The disposal should be managed in ways that reduce the level of risk to public health, water supplies, and the environment to acceptable levels. The waste should only be disposed of or treated at licensed premises. MSW management policies for effective MSW management system, which are implemented in developed countries and proposed for the developing countries, are given in Table 2-11.

Moreover, Ball (1999) recommended that any MSW management policy for low income countries should firstly focus on the basics (collection and disposal services) before moving towards advanced practices like those in developed countries such as cleaner production, recycling and treatment. The upgrading of collection systems or remediation or closure of existing open dumps to a controlled disposal site is preferable to developing new facilities.

Table 2-11: MSW management policies of various countries

Country	Management Policy
Denmark(1)	∉ Optimising waste disposal infrastructure ∉ Setting up a separate management scheme for individual material fraction ∉ Establishing central sorting plants and a biogas compost plant ∉ Introducing a double bag system to separate food waste from others to reduce chloride pollution and poor combustion value for WTE and obtain high quality compost ∉ Implementing pick up schemes and take away schemes for commercial waste ∉ Establishing waste classification system
China(3)	∉ Seeking for practices to reduce waste production ∉ Increasing recycling and composting ∉ Conducting studies on the reduction of solid wastes ∉ Advocating clean production processes
South Africa(4)	∉ Reducing waste volumes using waste minimisation and recycling processes with residual wastes being subjected to accelerated and integrated waste stabilisation processes in a landfill bioreactor
India(5)	∉ Maximising composting either aerobic and anaerobic and recycling practices ∉ Promoting source separation into biodegradable and non-biodegradable components.
Malaysia(7)	∉ Encouraging the reduction of waste generation especially packaging wastes and household wastes ∉ Treating MSW as a resource for recycling
Nigeria (8)	∉ Collecting and disposing solid waste in an environmentally safe manner ∉ Setting up and enforcement of laws, regulations, and standards ∉ Encouraging public participation ∉ Imposing penalties on defaulters to encourage compliance
United Kingdom(9)	∉ Ensuring that waste is recovered or disposed of without endangering human health and environment ∉ Ensuring self-sufficiency in waste disposal ∉ Encouraging waste prevention and recovery by means of recycling and reuse

Source: (1) Larsen and Boorild 1991; (2) Nuwayhid et al. 1996; (3) Wei, M. Wang and J. Wang 2000; (4) Korfmacher 1997; (5) Gupta et al. 1998; (6) Fehr, Castro and Calcado 2000; (7) Hassan et al. 2000; (8) Agunwamba 1998; (9) Williams 1998

A proper policy and plan for sustainable MSW management should also interact with policies for industrial development, population distribution, land use, public health, and other environmental issues, which are related to MSW problem (Rushbrook and Finnecy 1988). Importantly, sustainable MSW management policy must pay attention to all conditions supporting the regulation of implemented MSW management system, beside the technologies aspects. For example, an effective institutional structure should be established. Laws, regulations, and standards should be established and enforced. Public education and awareness should also be promoted. These issues are rarely addressed in the MSW management policy of developing countries.

2.6.4. REGULATIONS

Regulation is needed to ensure the implementation of the policy. Developed countries commonly have specific regulations for managing MSW unlike developing countries. The regulation can be at national, regional, or local levels (Bartone and Bernstein 1993). To fulfill the sustainable goal, regulations to ensure the proper treatment of all kinds of waste, the efficient running of implemented MSW management system, and the control of the impact on the environment and public health are required. Hazardous waste from entering the MSW stream must be prohibited to protect resources from contamination. Illegal dumping and littering must also be banned (Bartone and Bernstein 1993). Importantly, legislation addressing the allowable levels of discharge from management facilities such as leachate and air quality is required.

Besides the control over all treatment facilities to ensure the least environmental impact, regulations defining the authority and responsibility of government are also needed especially the duty for preparing a long-term management plan and educating the public as well as providing collection and disposal services (Korfmacher 1997). The role of the citizen in MSW management should be specified to enhance public participation. The example of MSW management regulations of these countries is presented in Table 2-12.

Table 2-12: Example of MSW management regulations in developed countries

Country	Law and Regulation	Content
Denmark[1]	∉ Environmental Protection Act	∉ Regulation of landfill
	∉ Recycling Act	
South Africa	∉ Environmental Conservation Act	
Germany	∉ The Waste law	∉ General principles of waste management ∉ Strategy of waste disposal ∉ National standard for landfill design ∉ Preparation of their own waste management plan according to the national interest
Japan[1]	∉ The Waste Cleansing Law (1900)	∉ Prevention of infectious diseases associate with waste
	∉ The Public Cleansing Law (1954)	∉ Protection of public health associated with waste management ∉ Construction of a solid waste incinerator and night soil treatment plants
	∉ The Waste Disposal and Public Cleansing Law	∉ Principle of municipal waste management, industrial waste management, and night soil treatment
The Netherlands[1]	∉ The Anti-Nuisance Act	∉ Protection against danger, damage and hindrance to people living in the vicinity
	∉ The Hazardous Waste Act	∉ Control of hazardous waste disposal
	∉ The Act on Waste Materials	∉ Control of waste disposal
	∉ The Water Pollution Act	∉ Control of leachate discharge
United Kingdom[1]	∉ The Control of Pollution Act	∉ Disposal of all controlled waste ∉ Control of waste generation and disposal facilities ∉ Preparation of a waste disposal plan ∉ Classification of waste for collection purposes
United States of America[1]	∉ The Resource Conservation and Recovery Act (RCRA) ∉ The Clean Air Act ∉ The Clean Water Act	∉ Preparation of an implementation strategy and plan ∉ Control of disposal practices
Australia[2]	∉ The Environmental Protection Act	∉ Role of waste management agencies

Source: (1) Bonomo and Higginson 1988; (2) The Aditor-General 2000

These regulations should be few in number, transparent, unambiguous, easily understood, equitable and considered to have significant positive physical and economic effects (Bartone and Bernstein 1993). In addition, waste management legislation should be integrated with all other relevant legislation (Ball 1999). Moreover, legislation should increase the flexibility of local authority to initiate the best management system for their region. Following the passing of MSW management laws, these regulations must be promulgated. Enforcement mechanism for the punishment addressed in the act must be developed.

In Taiwan (Lu et al. 2006), the Waste Disposal Act required the public to take their recyclable waste to waste-collection crews and fined people who throw recyclable waste with general waste. Local authority must collect and sort recyclable waste in which central government helps purchasing recyclable truck through recycling fund. Specific recycling policies are far more important than socio-economic variables. Mandatory recycling program had twice the participation compared to voluntary program. Research found that the more education, the higher recycling rate (Lober 1996).

Countries that have specific laws on reducing packaging waste include Germany, Denmark, U.S., Canada, Sweden and Japan (Sakai et al. 1996). However, Japan and Germany are the two most aggressive nations in the world when it comes to the promotion of recycling and waste reduction (Lu et al. 2006). In German, law on the prevention and Disposal of waste 1986 and Closed Loop Economy Law 1994 were enforced (Sakai et al. 1996) with Dual System Germany (Vehlow 1996; Lu et al. 2006). In Japan, local authority is obliged to begin collecting plastic and paper packaging waste separately from other household waste. Producers and retailers must recycle these packaging wastes by designated privately owned recycling agent (Sakai 1996; Kofoworola 2006)

2.6.5. PUBLIC PARTICIPATION

Besides the government, there are other important stakeholders to achieve sustainable MSW management system including private company, manufacturer, academics, NGOs, and public. Their roles to MSW management system are presented in Figure 2-11. These stakeholders must work collaboratively as it relates each other.

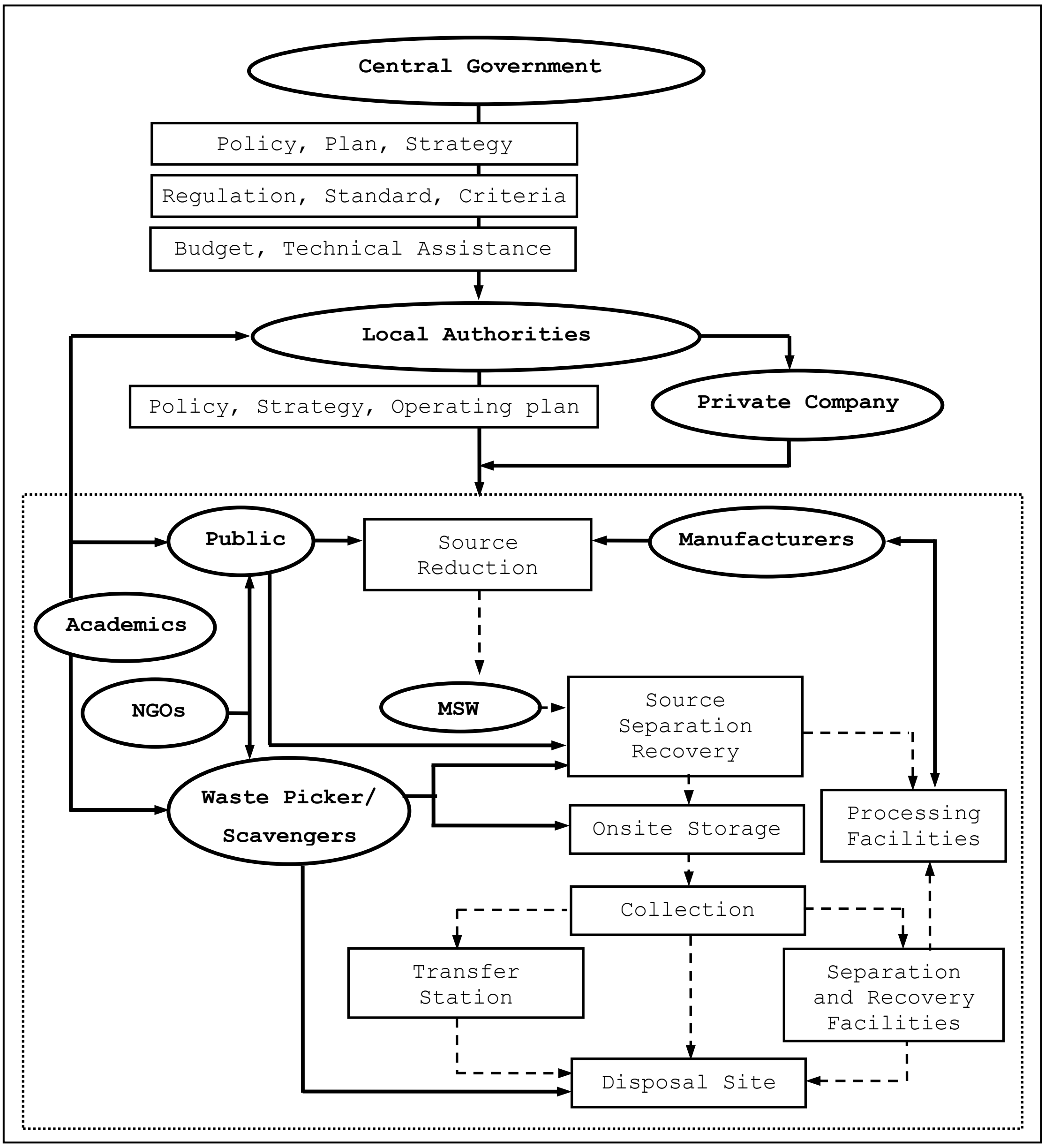


Figure 2-11: Relationship of MSW management stakeholders

Therefore, the success of MSW management depends on the capability of local authorities and their relation with other stakeholders. In many countries, local authorities contract private companies to provide the services, from collection, incineration, or disposal process or so called Public Private Partnership (PPP) scheme (Rathi 2006; Parrot, Sotamenou and Dia 2009). The role of each player is illustrated in Table 2-13. Various studies (Arlosoroft 1991; Bartone 1991; Bartone and Barnstein 1993; Schubeler 1997) have illustrated that private firms can be more productive and efficient in carrying out collection and transport operation than local authorities, however, as long as the requirements for contestable markets are met.

Table 2-13: Roles of stakeholders in Public Private Partnership (PPP) scheme

Local authorities	**Private sector**
∉ Collection of waste from community bin ∉ Transportation of waste to private sector compound ∉ Disposal of non-biodegradable and non-recyclable materials	∉ Capital investment for processing organic waste ∉ Conversion of organic waste into compost ∉ Marketability of compost

Source: Rathi 2006

According to the experiences of various countries, it is found that private sector can successfully work in upper class areas which can pay for high service charge. However, it may not work in suburban area where the service charge may not be affordable. Moreover, the services should be privatized in middle to upper income area while the service in low income areas should remain the responsibility of local authorities (Henry, Yongsheng and Jun 2006). In many developing countries, another implementing scheme has been utilized, so called Community Based Organisations (CBOs) which is the cooperation between local groups such as NGOs, CBOs and local government (Rathi 2006; Parrot, Sotamenou and Dia 2009). The role of each player is given in Table 2-14.

Table 2-14: Roles of stakeholder in Community Based Organisations (CBOs) scheme

Local authorities	NGOs	CBOs
∉ Collection, transportation, and disposal of non-biodegradable and non-recyclable materials ∉ Looking after the complaints of communities participating in waste management program	∉ Training rag pickers ∉ Coordinating between CBOs and local authorities	∉ Collection of waste from households ∉ Composting of organic waste ∉ Payment of salary of rag pickers

Source: Rathi 2006

Waste pickers or scavengers are another group of key players of MSW management particularly in developing countries as they buy materials from residents, sort from waste containers and recover from open dumps. These recovered materials are sold through middlemen or dealers, who sort and pretreat the materials before selling to industries/manufacturers (Muttamara, Visvanathan and Alwis 1994; Wilson, Costas and Cheeseman 2006). Manufacturer then plays both roles in minimising waste by redesigning their product and using recovered materials as their raw materials to sustain recycling business.

Community involvement is crucial for the success of any solid waste management programs (McDonald and Ball 1998; Novella 1999). Without public contribution, the most well thought source recovery program would fail (Everett et al. 1998). They are involved in sorting out recyclable materials from their household and putting bins by the curbside on the collection day. Involving local people in planning and decision making process as well as monitoring of treatment or landfill operations is essential for success of the management strategy (Agapitidis and Frantzis 1998; Ball 1999). To enhance their participation requires intensive and persistent education (Lober 1996; Agunwamba 1998). Academic institution and NGOs are then key players for educating the public besides local authorities.

Intensive and persistent education programs must be implemented to enhance public awareness (Agunwamba 1998). A good public relations office in each regional municipality should be developed (Abduli 1995). The public must understand their role in the management system and co-operate with the local authorities for the system to work. Moreover, local people should be given the opportunity to monitor and influence the management of the treatment or landfill operations (Agapitidis and Frantzis 1998). Local authorities should involve the public throughout the planning and decision making process. Involving representatives of all interested parties is essential for success of the management strategy (Ball 1999).

2.7 MSW MANAGEMENT PLANNING SYSTEM

As discussed in the previous section, building the planning capability of local authority should be the first priority in order to enhance the performance of MSW management system. This section thus further reviews the structure of proper MSW planning system that should be established in local authorities. An effective MSW planning system should carry out appropriate planning procedures, design MSW management system that meets local conditions including MSW characteristics, operating skills, budget, and public participation, and produce MSW management plans with all necessary information for implementation.

2.7.1. PLANNING PROCEDURE

Various planning procedures have been recommended to ensure the comprehensive planning output (Yuill 1970; Wilson 1981; Haynes 1981; Rushbrook and Finnecy 1988; Schall, Geller and Horton 1993; Wang, Richardson and Roddick 1998; Clarke, Read and Phillips 1999). However, the key steps are similar including problem diagnosis and definitions, goal and objective setting, strategy development, and operational plan development as summarised in Figure 2-12 (Sakulrat and Darnsawasdi 2009).

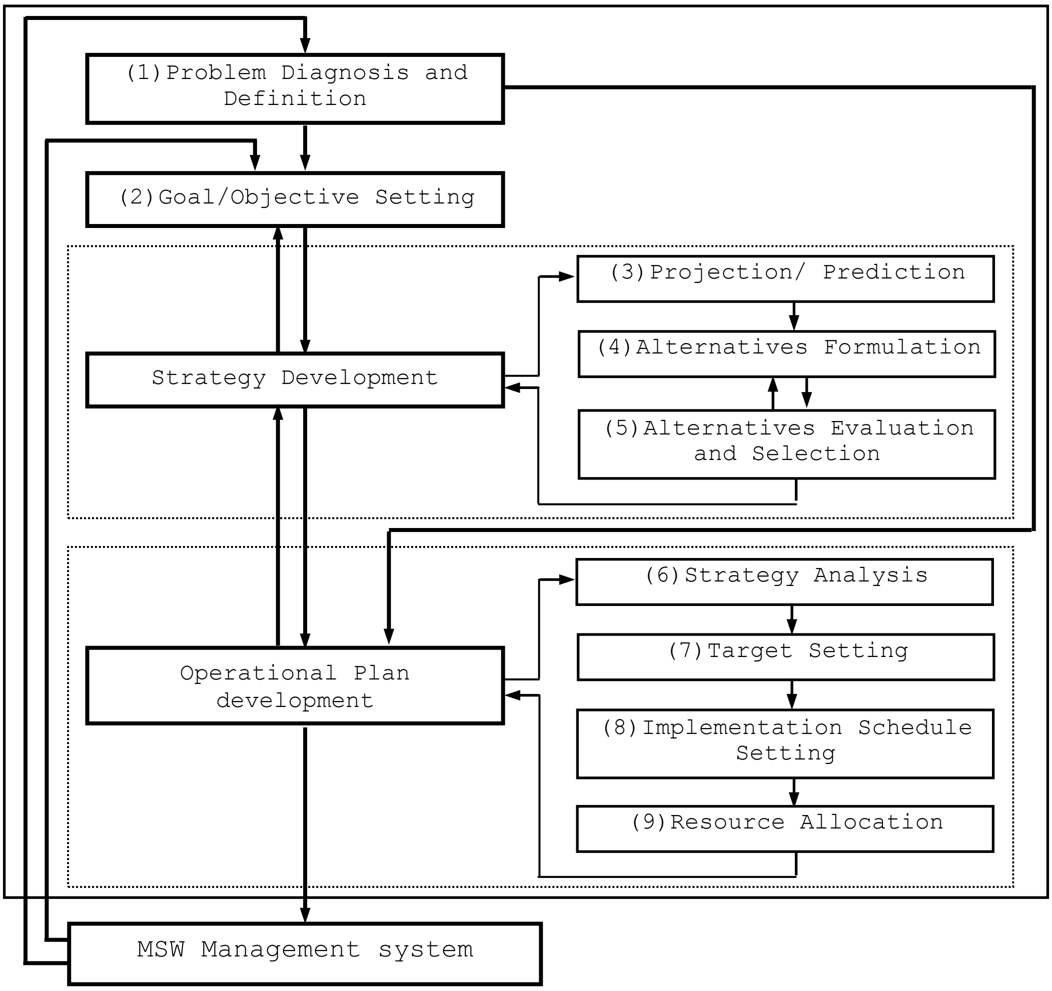


Figure 2-12: MSW planning procedure

2.7.1.1. PROBLEM DIAGNOSIS AND DEFINITION

Planning activities in the field of solid waste management are generally undertaken when the problem of MSW management system has been recognised or the community and mandatory needs have been changed (Tchobanoglous, Theisen and Vigil 1993). The first step is to determine the weaknesses and causes. Right corrective actions can then be designed. Effective solutions cannot be developed without clearly knowing the characteristics of the problems.

The objective of sustainable MSW management system is to minimise waste going to final disposal sites, in which the environmental impact can be reduced, by reducing and recovering waste as much as possible. Moreover, generated waste must be stored, collected, and treated in an environmental friendly manner. The collection process should concern the sufficiency and access of containers provided, and the collection and transportation capacities of collection vehicles. Meanwhile, the main considerations of treatment processes including recycling, composting, and incineration and disposal service are facilities capacity and environmental impact.

According to these concerns, general questions summarised in Table 2-15 can be used to identify the performance or weaknesses of MSW management system.

Table 2-15: Evaluation questions of MSW management systems

Component	Question
Onsite Storage	∉ Is access readily available to all provided containers? ∉ Can all generated waste be stored in the provided containers? ∉ Is the type of provided container compatible with the weather, types of waste, collection service and collection vehicles?
Collection and transport	∉ Can all provided containers be emptied on their collection day? ∉ Is any waste left outside the containers on collection days? ∉ Is the number of collection vehicles, street sweepers and collection crews compatible with the loads? ∉ Is the work fairly assigned to each street sweeper and collection team? ∉ Is the collection cost compatible with the quantity of collected waste? ∉ Is the collection cost kept within the available budget?

Table 2-15: Evaluation questions of MSW management systems (con't)

Component	Question
Materials Recovery Facility	⊄ Is recyclable material constantly supplied to the recovery facility? ⊄ Is the capacity of the facility compatible with the quantity of incoming waste? ⊄ Is the number of workers compatible with the load? ⊄ Are the emissions from the recovery facility within the standards? ⊄ Does the quality of recovered material meet the market requirements? ⊄ Does the material recovery rate meet national requirements/policies?
Composting Facility	⊄ Is the characteristic of incoming waste suitable for composting? ⊄ Is compostable material constantly supplied to the facility? ⊄ Is the capacity of the facility compatible with the quantity of incoming waste? ⊄ Is the number of workers compatible with the load? ⊄ Are the emissions from the composting facilities within the existing standards? ⊄ Does the compost quality meet the market requirements?
Incineration	⊄ Is the characteristic of the incoming waste suitable for incineration? ⊄ Is combustible material constantly supplied to the facility? ⊄ Is the capacity of the incinerator compatible with the quantity of incoming waste? ⊄ Is the number of workers compatible with the load? ⊄ Are the emissions from the incinerator within the existing standards?
Disposal	⊄ Is the number of equipment compatible with the load? ⊄ Is the number of workers compatible with the load? ⊄ Are the emissions from the site within the existing standard? ⊄ For how long can the disposal sites be used?

Sources: Quon, Tanaka and Wersan 1969; Clark 1973; Partridge and Harrington 1974; Rhyner et.al.1995; Anex et al. 1996; Daskalopoulos, Badr and Probert 1997

The answers to these questions provide the understanding of current performance of overall MSW management system and individual process whether the objectives of sustainable MSW management system are fulfilled. Accurate causes of deficiencies can subsequently be determined such as the compatibility of incoming wastes quantity and quality and the sufficiency of manpower, equipments and financial resources. Appropriate solutions to enhance the performance can then be designed. These questions, however, primarily concern over the efficiency and environmental performance. More specific questions subject to economic and social aspects such as the cost effectiveness or public satisfaction should also be asked.

2.7.1.2. GOAL AND OBJECTIVE SETTING

The second step then sets the direction of actions that will address the weaknesses of existing MSW management systems determined from the first step. Goals and objectives indicate where the organisation wants to go, what it is expected to accomplish (Gordon 1993), and subsequently what actions to take. Clear goals and objectives are necessary not only for designing and evaluating alternatives in the next step, but also for checking the success of MSW management systems implemented.

The description of goal and objective are various and frequently used synonymously. However, in this study, goals are rather general (Branch 1983) and tend to be relatively few in number, not very specific, and non quantitative (Gordon 1993). Objectives are more specific and are quantitative but in line with the goals. Thus, the goals of entire MSW management system could be to dispose of waste at the least possible cost to the community or least adverse effect on the environment or to maximize the resources conservation (Wilson 1981). Goal for each service can also be set. For example, the goal of recovery service can be to maximize recyclable materials rate or to reduce the amount of waste generated at the source (Tchobanoglous, Theisen and Vigil 1993).

There are many kinds of objectives (Branch 1983). Some are short-term (1-2 years), medium-term (3-5 years) or long-term (15-20 years). Objectives for individual service can also be set out to achieve the overall objective. These can be 100% of collection efficiency, 25% of composting, or 50% incineration. Goals and objectives should be set based on available resources and existing circumstances. Goals express what should be done while objectives expresses what can be done.

2.7.1.3. STRATEGY DEVELOPMENT

Once the goals and objectives have been stated, a strategy is developed to describe the pathway to accomplish them. Waste management strategy usually focuses on improving the entire MSW management system, by specifying technologies to be utilized, locations to be built, and stakeholder to be involved to fulfill the goals (Clark and Gillean 1981; Wilson 1981). Various choices of alternative are formulated and analysed to determine an optimum way to achieve the goals. A few key steps are undertaken when designing MSW management strategy, including the projection of amount of MSW and the availability of resources to handle the projected amount, the formulation of MSW management alternatives, and the evaluation and selection of alternatives.

2.7.1.3.1. Projection

There is a need to predict the future in order to estimate demand for facilities and services, and to assess our capacity to meet projected needs (Alexander 1986). The common projection in MSW management is quantity and composition of MSW. Information on the quality and composition of MSW is required to design appropriate treatment methods. For example, in case the proportion of plastic and paper packaging dominate the waste stream, recycling or incineration may be more interesting choice than composting. The quantity is needed to design the capacity of the facilities (Klee 1993). The success of MSW management system is then related to the accurate determination of waste quantity and composition, both at present and the future.

The composition of MSW is affected by socio-economic factors, industrialise level, climate and season, consumption level, legislation, and public attitude (Ali Khan and Burney 1989). Meanwhile, the generation of MSW is linked to the economic and population growths. The forecast then needs to take all these factors into account. Complex mathematical estimation techniques are then needed to determine the correlations of these factors to the quantity and composition of MSW. Various models and techniques have been developed to handle these issues such as time-series analysis (Rushbrook and Finnecy 1988), linear regression analysis (Abu Qdais, Hamoda and Newham 1997), multiple linear regressions (Lohani and Hartono 1985; Ali Khan and Burney 1989).

Resources such as budget, equipment, land, technology, and human resources as a supply side also need to be estimated to ensure that future demands can be met. The projection is also carried out once the alternatives are developed to determine the impacts of alternatives under possible future conditions.

2.7.1.3.2. Formulation of Alternatives

According to the predicted quantity and composition of MSW and the available resources, a set of alternative MSW management systems can be developed. The formulation of management strategy is then about the selection of most technologies and potential locations. List of alternatives can be obtained from brainstorming or check-listing procedures in which lists of key words or concepts are used (Dickerson and Robertshaw 1975).

At present, the overall goal of MSW management system is to reduce waste going to land disposal. There are two main choices for managing waste at source either all generated waste should be separated at source or sent to central sorting facilities. Subsequently, the choices of transferring waste stored at sources to disposal sites are formulated. Fundamentally, waste is transferred directly from sources to its final disposal site.

The second choice is that a transfer station is used to improve collection and transportation efficiency. Waste from transfer station can either be transferred to processing facilities or disposal sites. The third choice is transported to processing facilities to alter the waste volume to improve disposal efficiency. Once the pathway is selected, the following aspects in Table 2-16 should subsequently be designed and addressed in the strategy for each service. These include the schedule for implementing each facility, the technologies of each facility, and the capacity of each facility.

Table 2-16: Design aspects of MSW management system

Component	Aspect
Source separation	∉ Recovery and separation rate for each waste component
Materials Recovery Facility	∉ Time to recover each waste component (scheduling) ∉ Technologies for recovering each waste component ∉ Capacity of selected technologies
Recycling Facility	∉ Production rate of each waste component ∉ Time to recycle each waste component (scheduling) ∉ Technology for recycling each waste component ∉ Capacity of selected technologies
Composting Facility	∉ Production rate ∉ Time to compost waste (scheduling) ∉ Technology for the composting process ∉ Capacity of selected technologies
Incineration	∉ Composition of incoming waste ∉ Time to incinerate waste (scheduling) ∉ Technology for the combusting process ∉ Capacity of selected technologies
Disposal	∉ Composition of incoming waste ∉ Technology for the disposal process

2.7.1.3.3. Evaluation and Selection of Alternatives

All alternatives are subsequently evaluated to seek the best pattern of handling the MSW quantitatively and qualitatively subject to given criteria (Wilson 1981). This step is essential to ensure that the chosen alternative meets most, if not all, existing conditions to maximise the effectiveness. Regarding the concept of sustainable MSW management, evaluation criteria commonly relate to economic, technical, and environmental aspects (Wilson 1981; Rushbrook and Finnecy 1988; Schall, Geller and Horton 1993; Wang, Richardson and Roddick 1998; Daskalopoulos, Badr and Probert 1997; Wilson, McDougall and Willmore 2000). Any selected strategy should be affordable, effective, and acceptable to both community and local authorities. An example of evaluation aspects subject to each service is given in Table 2-17.

Table 2-17: Evaluation aspects of MSW management alternatives

Component	**Evaluation Aspect**		
	Technique	**Economic**	**Environment**
Onsite storage	- Population numbers with access to the containers - Capacity	- Capital (containers, land)	
Collection and Transportation	- Collection time - Collection efficiency	- Capital (equipment) - Operating (labour, fuel) - Maintenance	- Exhaust gases (CO_2, NO_x, CH_4) affecting global warming
Treatment (Recycling, composting, incineration)	- Power requirements - Recovery rate - Quality of product - Material conservation - Energy conservation	- Capital (construction, equipment, land) - Operating (electricity, fuel, labour) - Maintenance - Market	- Exhaust gases (CO_2, NO_x, CH_4) affecting global warming - Water from processing - Residue from processing
Disposal (Landfilling)	- Compaction - Amount of waste covered at the end of day	- Capital (construction, equipment, land) - Operating (electricity, fuel, labour) - Maintenance	- Emission gases (CO_2, CH_4) affecting global warming - Runoff - Leachate

Technical aspects mainly find out the capability of proposed system to handle all generated waste and to meet the technical objectives of sustainable MSW management, for example the capability to divert waste from disposal and to conserve material and energy. Economic aspects determine the budget needed for capital, operating, and maintenance costs of proposed system as well as the possible income such as from selling recovered materials or energy. Meanwhile, environmental aspects find the impacts of proposed system on the quality of air and water resources. Social aspects commonly determine the public acceptance, satisfaction, and participation towards the proposed management system.

The evaluation results can be displayed as a simple matrix, comparing the performance of all alternative subject to each evaluation criteria. The best option should also be selected based on the existing conditions such as physical characteristics (climate and seasonal variation and land use), policy, regulation, and available resources as summarised in Table 2-18 (Rushbrook and Finnecy 1988; Tchobanoglous, Theisen and Vigil 1993; Sakai et.al. 1996).

Table 2-18: Conditions for MSW management alternative selection

Issues	Aspect
Policy, legislation, management and institutional structure	∉ Regional plan ∉ Political support ∉ Institutional and administrative structure for MSW management ∉ Managerial capacity and personnel stability ∉ Regulations and site specifications
Resources	∉ Infrastructure and waste disposal security ∉ Existing contractual obligations ∉ Location and demography ∉ Available versus proven technology ∉ Available funding/ subsidies/ budget ∉ Secondary materials market

As various criteria are considered, the selection process can be simplified by firstly evaluating each alternative on the basis of the most important criteria and eliminating unfeasible alternatives. Those remaining are further evaluated using more comprehensive criteria (Dickerson and Robertshaw 1975). Another approach to ease the selection process when various criteria are taken into account is called a multi-criteria evaluation technique.

This technique forms an evaluation matrix, containing information of alternatives subject to all criteria. The matrix is two dimensional, with the evaluation criteria forming the rows and the alternatives forming the columns (Maimone 1985; Powell 1996). Example of the evaluation matrix is presented in Figure 2-13 (Chung and Poon 1998).

	A1	A2	A3	A4	A5	A6
Cost						
(Internal cost)	0.00	0.11	0.00	0.11	0.67	1.00
(Transport cost)	0.00	0.00	0.00	0.00	1.00	1.00
Resource use						
(Land use)	0.83	0.83	1.00	1.00	0.00	0.00
% waste eliminated	0.82	0.76	1.00	0.99	0.26	0.00
Energy recovered	0.66	0.31	1.00	0.60	0.61	0.00
% materials recovered	0.93	0.14	1.00	0.21	0.86	0.00
Waste categories handled*						
Ease of materials recovery*						
Environmental Impacts						
(Transport)	0.00	0.95	0.00	0.95	0.03	1.00
% waste incinerated	0.75	1.00	0.17	0.27	0.00	0.00
(Local air pollution)	0.60	0.59	0.84	1.00	0.25	0.00
(Global air pollution)	0.55	0.00	1.00	0.61	0.69	0.15
Water/Soil pollution*						
Relative concentration toxic substances*						
Disamenity*						

Figure 2-13: The evaluation matrix of multi-criteria evaluation technique

The following steps are then carried (Wilson 1981; Chung and Poon 1998):

1. evaluate each alternative against each criterion both cardinal and ordinal criteria
2. normalise the scores to a common numerical basis, such as score out of 1
3. weigh each evaluation criteria relatively, and
4. obtain a single numerical score or index of performance for each alternative by combing the normalized scores of each option against each criterion with the relative weights of each criterion

It is clear that developing an appropriate MSW management system that meets all requirements is very difficult. However, the selected alternative should meet as many as possible of the following criteria in order to move towards sustainable MSW management system:

∉ all collected waste are sanitarily treated and/or disposed of

∉ the targets for waste recovery rates are achieved

∉ the overall cost is affordable

∉ the environmental impacts are acceptable

∉ the system can handle all generated waste throughout the life of the planning period, and

∉ the system should gain acceptance from the local community before the final decision is made.

Once the decision is made, an equipment acquisition plan, a long-term budget, a maintenance programme, and a new administrative system of the selected alternative should be developed.

2.7.1.4. OPERATIONAL PLAN DEVELOPMENT

Once the strategy is selected, it is subsequently turn into a series of operational plans (Wilson 1981; Gordon 1993). It can be long-term (five years or more), medium-term (two to five years), or short-term (usually one year) operational plan. Operational planning allocates resources and sets up implementation schedule (Higgin 1980). It evaluates and ranks the actions addressed in the strategy, and translates the results into schedules, resource requirement, and actions.

The steps undertaken to develop an MSW operational plan are as follows. The selected MSW management strategy is firstly analysed to break down the actions to be implemented. A timeframe for each action based on the priority is subsequently set up. Finally, the resources (personnel and equipment) are allocated to the designed tasks. The plan may be split into a day-to-day operating plan and project/program plan. Accordingly, the issues generally considered in the operational planning are listed in Table 2-19.

For onsite storage, location, number, size and type of waste container is detailed, followed by the routings and scheduling of collection vehicles and street sweepers. The number, size and type of collection vehicles and crews and street sweepers are then assigned. Types of treatment facilities are defined, with the number of workers at the sites, routing and scheduling of transferring processed waste to subsequently facilities, and number and types of vehicles and crews. At disposal site, working pattern is designed, followed by scheduling and type and number of equipment and workers. Responsibilities of relevant personnel are finally designated.

Table 2-19: Issues concerned with the operational planning

Component	Issues
Onsite Storage	∉ Location of each container ∉ Number of containers at each pickup location ∉ Sizes and types of containers at each pickup location
Collection and transport	∉ Optimal routing and scheduling of each collection vehicle ∉ Number, sizes and types of collection vehicles on each collecting route ∉ Number of members of collection crew on each collection vehicle ∉ Optimal routing and scheduling of each street sweeper ∉ Number of street sweepers on each collecting route
Material Recovery Facility	∉ Number of workers for processing ∉ Number and type of transport vehicles from facility to each destination (recycling facilities, disposal sites)
Composting Facility	∉ Number of workers for processing ∉ Number and type of transport vehicles required from facility to each destination (market, disposal sites)
Incineration	∉ Number of workers for processing ∉ Number and type of transport vehicles from facility to disposal site
Disposal	∉ Number of workers for processing ∉ Number and type of machine and equipment ∉ Working pattern of machine

2.7.2. PLANNING OUTPUT

Once the planning process is completed, planning output must be properly documented in a form of MSW management plans containing necessary information for implementation. Accordingly, MSW management plan should be prepared in three format including strategy, project/program plan, and day-to-day operating plan. Importantly, these MSW management plans must be related to each other (Sakulrat and Darnsawasdi 2009) and easily understood by the user.

The plans should also be properly organised so that anyone – inside the department or from other departments – can conveniently access them when needed.

The strategy should contain information about the background of the region (e.g. socio-economic trends, demographics and waste quantities), specific quantitative objectives, and the overall structure of the management systems. Programs then deal with individual components of the management systems (e.g. collection or recovery or disposal processes) or specific objectives that are addressed in the strategy. The typical contents of a project/program plan are operating details, staffing requirements, equipment procurement (Tchobanoglous, Theisen and Eliassen 1977), schedules, and technical parameters of particular components (King and Cleland 1978).

A day-to-day operating plan provides precise instructions and specifications required to perform each process of the MSW management system according to the timeframe set in the programs. The content may include collection routing and scheduling with corresponding crews or the working pattern of each crew and the equipment at the disposal site.

2.7.3. PLANNING SUPPORT COMPONENTS

As mentioned in Section 2.7.1, proper MSW planning system should carry out nine planning steps and produce three types of MSW management plan. Based on the experiences of various countries, the effectiveness of planning system depends on the performance of six key components including (Sakulrat 2006)

(1) information management system,

(2) decision support system,

(3) planning management system,

(4) planning staff,

(5) planning facilities, and

(6) organisation administrative structure

The relationship of these components is illustrated in Figure 2-14 (Sakulrat 2006; Sakulrat and Darnsawasdi 2009). Brief details of each component are described below.

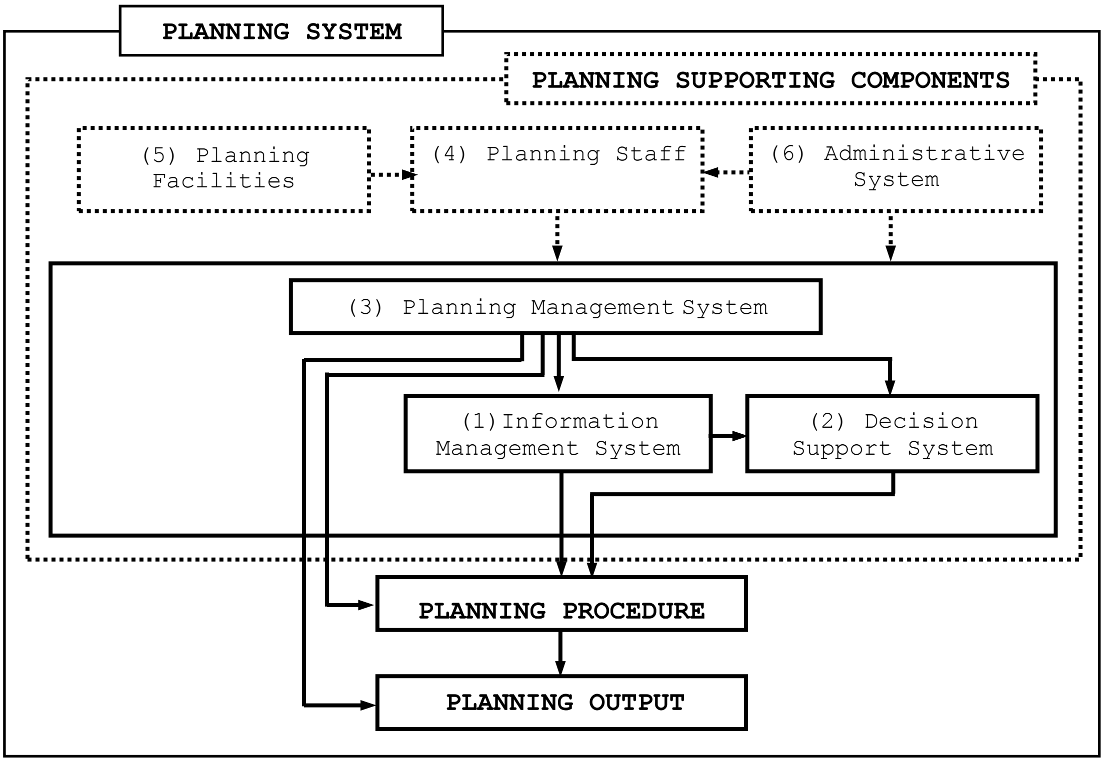


Figure 2-14: The Structure of an effective MSW management planning system

2.7.3.1. PLANNING STAFF

The capability of planning staff is the most important factor. They are always the prime suspects when any problem occurs. Appropriately trained and experienced staff is essentially required as MSW management planning process is complex (Rushbrook and Finnecy 1988; Bartone 1991; Kerzner 1998). Although external specialists can help, it is essential to develop human resources, if sustainability is to be achieved (Ball 1999).

Staff should be qualified in one of the natural sciences or engineering who has broadened his knowledge into these areas (Rimberg 1975). Managing MSW requires the understandings on MSW characteristic, engineering process, as well as planning process (Ball 1999). Despite the individual academic background, involved planning staff must be equipped with factual information before starting the process (Mercer 1991) and their responsibilities should be clearly defined without any unnecessary overlapping of work (Bartone 1991). There is a need of system to ensure that planning staff is given clear instructions on the nature of their jobs and responsibilities to maximize their performance (Rushbrook and Finnecy 1988). Moreover, responsibilities and channels of communication must be clearly defined (Ball 1999).

The commitment of the planning staff assigned to the jobs is also critical for their success of the planning process (Mercer 1991). Incentives to motivate and encourage the commitment of the planning staff should also be provided. This can be done by making a strong and visible commitment to the planning, setting realistic expectations, giving providing top priority to planning process, minimizing planning-related paperwork, and clarifying their roles in planning process.

Moreover, training in the concepts and processes of planning must be provided to the staff to ensure capacity and competency (Ball 1999). Planner must continue to develop their planning skills and general knowledge related to MSW management such as legislation (Soesilo and Wilson 1995). This can be accomplished by (1) encouraging management and technical training in colleges and universities, (2) arranging for field courses and demonstrations, (3) providing special training for operating personnel to prepare them for certification examinations (Rimberg 1975), (4) hiring an outside facilitator or consultant, (5) sending key staff to seminars or workshops, through self-study, through experimentation, or (6) borrowing from private sector (Mercer 1991).

2.7.3.2. INFORMATION MANAGEMENT SYSTEM

Producing effective planning output and MSW management system needs accurate and adequate relevant information (King and Cleland 1978; Rushbrook and Finnecy 1988; Wilson, Whiteman and Tormin 2001). The effectiveness of any future MSW management system largely depends upon the quantity and quality of this data/information (Wilson, Whiteman and Tormin 2001). The reliability of collected information is also essential. The manner in which this available data is handled and used is also critical.

Proper information management system ensures that all required information is collected on a regular basis, reliable, and properly handled and organised. Fundamental data required are the efficiency, cost and environmental impacts of onsite storage, collection and transportation, treatment and disposal services. Other data includes MSW quantity and generation rate and MSW physical and chemical composition. These are used to set up alternative MSW management systems and evaluate for selection.

To carry out the nine steps effectively, data on the existing MSW management system is required first to determine the extent and form of the problem and the available resources. This includes data concerning the efficiency, cost and environmental impacts of onsite storage, collection and transportation, treatment and disposal services. For onsite storage and collection, data on the provision and access of container and collection capacity is needed. Meanwhile, information on facilities capacity and environmental impact are the main concerns with respect to the treatment and disposal services. Overall, data on the recovery rate and estimated lifespan of the disposal site is needed.

Other data required include the quantity and quality of MSW and the generation rate per capita per day, the generation growth rate, the physical and chemical composition of MSW, and the population growth rate. These are used to set up a set of alternative MSW management systems. Data to evaluate the performance of each alternative system is then needed for the selection.

2.7.3.3. DECISION SUPPORT SYSTEM

Making decision is a crucial step of planning process and must be carried out systemically. Strong evidence and sufficient information is essential to minimise the failure risk. Decision support system ensures that planning staff make all decisions based on scientific evidence, not perceptions where the performance of existing and proposed MSW management systems should be evaluated against four criteria, including efficiency, economic, environmental impact and social impact. According to the step of strategy development, information on the performance of existing and proposed MSW management systems is required. Thus, the decision support system ensures the flow of information from the information management system for the evaluation of each choice against each assessment aspects.

The decision support system also arranges brainstorming or formal meeting among the planning team and public hearings to obtain the information for selecting the most suitable management system. The latter is very significant. The acceptance of the community is a crucial factor for the success of MSW management system particularly the selection of land disposal site due to NIMBY syndrome. The best way to achieve this acceptance is to involve of key community groups in the decision making process or to demonstrate that the strategy is compatible with other goals of the community, such as urban renewal and industrial development (Tchobanoglous, Theisen and Vigil 1993).

2.7.3.4. PLANNING SUPPORT SYSTEM

Planning process at present needs computer facility to store intensive information collected or create MSW database and to carry out comprehensive analysis before making final decision. The choice of a computer system for planning will depend upon various technical and economical considerations and on the systems already available within the organisation (Higgin 1980). The general criteria to select suitable computer facility are reliability, ease of upgrading and modification, supports, and sales relationships.

In addition to hardware, analytical software for complex calculations (Higgin 1980; Rushbrook and Finnecy 1988; Yhdego, Vida and Overgaard 1992; Anex et at. 1996) should be provided to planning staff to reduce planning time and difficulties, which could exceed the ability of planning staff. The limitations of the planning staff can be minimised and their working flexibility and capabilities can then be enhanced. This then gives more reliability to the planning system. However, the reliability of these tools also depends on the quality of data input.

The applications of these softwares at present include forecasting waste quantity and composition, allocating waste from collection points to disposal sites; routing of collection vehicles; ranking of disposal alternatives; and location of SWM facilities such as transfer stations, processing plants, and disposal sites, formulating a suitable management system, evaluating each pattern of the management system, determining optimal choice under given criteria, and calculating cost and emissions of each alternative MSW management systems.

Various analytical models for collection services have been developed with the applications to queue problems at the disposal point, to investigate the effect of a proposed transfer station, to locate transfer station, and to select collection vehicle route and schedule (Clark and Gillean 1974). Various statistical methodologies are developed for analyzing and forecasting generation rates, population, economic conditions, and future land uses. The Program Evaluation and Review Technique and Critical Path Method (PERT/CPM) and the Planning-Programming Budgeting System (PPBS) and Operational Research are increasingly used (Rimberg 1975).

Sufficient budget specifically for planning activities (acquiring facilities and organising training course) is then necessary to ensure the effectiveness of the unit. Planning tools and facilities need upgrading consistently.

2.7.3.5. PLANNING MANAGEMENT SYSTEM

The planning process must itself be planned and properly managed as planning is a time and resource consuming activity. The planning management system is then implemented to ensure the readiness of planning staff. The role of the planning management system includes identifying and inviting participants, scheduling meetings and establishing deadlines, and ensuring that necessary follow-up steps are taken (Gordon 1993) to ensure that proper arrangement of planning process is carried out in an orderly manner.

Preparation of the planning work plan is one of the means to control the planning process. The processes that will be performed over the planning period to develop the MSW management plan are documented and described in sufficient detail so that it is well understood by the planning staff and line personnel can cooperate with it readily (QED 1989).

This planning work plan can be developed in the form of a network diagram that depicts the activities and events of a planning effort (King and Cleland 1978). The planning work plan is also a tool to control the MSW management planning unit. Similar to the control of the MSW management system, the planning work plan is used to assess whether the planning system is working properly and to determine what can be improved to make the planning system works better. The evaluation aspects include planning input, output, sequence, resources, and the environment (King and Cleland 1978).

The planning work plan should address the following aspects: scope of planning (area, period, waste types and service levels), tasks required, methodology to be applied, responsibilities, key communication mechanism (Wilson, Whiteman and Tormin 2001), the meeting place, the frequency of meeting (Mercer 1991). Knowing this information will enhance the likelihood of putting the right person into the right job. This planning work plan will provide a better understanding of the planning process and gain commitment from all relevant staff.

2.7.3.6. ADMINISTRATIVE SYSTEM

Another factor that affects the performance of planning staff is the administrative structure of the organisation. The success of long-range planning in an organisation is more sensitive to its culture than the planning techniques used (King and Cleland 1978). It reflects the working conditions required to maintain a stable and competent work force (Rimberg 1975). The administrative structure affects the distribution of responsibilities and authority; interactions/ information flow between departments; institutional capacities; and personnel administration (Wilson, Whiteman and Tormin 2001).

Organisational structure also affects the information available to planning participants and the nature of the information flows among participants (King and Cleland 1978). A proper administrative mechanism ensures the regular supply of up-to-date data (Rushbrook and Finnecy 1988). Insufficient attention to building institutional capacity or unclear institutional structure and responsibilities could then cause problems for MSW management systems (Bartone and Berstein 1993).

Waste management organisation could benefit from a specialist forward planning department, separate from the supervisory and operations staff (Bartone 1991; Gordon 1993). This one unified department carries out all planning issues related to MSW management system (from source to disposal sites). The connections between each service can then be considered. The interdependencies among these services are very significant and ignorance could result in low cost effective system (Clark and Gillean 1974). Dividing of responsibilities of organisational planning bodies could make the preparation of a coherent and cohesive waste management strategy becomes increasingly difficult (Wilson, McDougall and Willmore 2000).

2.8 MSW PLANNING SUPPORT TOOLS

A computer-based tool becomes important to the MSW planning process since intensive analysis needs to be carried out to cover all evaluation aspects including efficiency, economic, and environmental and social impacts regarding the concept of sustainable MSW management system. The process is clearly time-consuming, which could exceed the ability of planning staff.

Various analytical support tools have been developed to address this problem. Early stage in 1970s, the applications of these tools focus on specific aspects include allocating waste from collection points to disposal sites; routing of collection vehicles (Truitt, Liebman and Kruse 1969; Bodner, Cassell and Andros 1970; Clark and Helms 1972; Liebman, Male and Wathne 1975; Male and Liebman 1978); and siting SWM facilities such as transfer stations, processing plants, and disposal sites (Esmaili 1972; Popovich, Duckstein and Kisiel 1973; Huhner and Harrington 1975).

In 1980s, MSW models extended boundaries of 1970s models (Morrissey and Browne, 2004). These models covered MSW management at the system level, by considering the relationship between each activity rather than individuals. Recycling was included (Khan and Burney 1989; Milke and Aceves 1989; Lund 1989). Minimising cost of management system was a main aim of models developed in this time. Simulation and optimization were then techniques used in MSW analysis models developed during 1970 to 1990. Spreadsheet and linear programming software were common packages.

In 1990s, MSW models considered a full range of waste stream and available waste management practices under integrate waste management concept to select a preferred option (Morrissey and Browne, 2004). Common application is to evaluate the performance of alternative MSW management systems regarding financial and environmental aspects and to determine optimal choice under given criteria. However, few consider social aspects. Examples of MSW management system analysis tool with their applications are presented in Table 2-20.

Table 2-20: Examples of MSW management system analysis tool

Model	Application	Technique/ Tool
SWAP[1] (U.S. 1992)	**Determine** optimal allocation of waste from source to facilities on the basis of least cost	Linear programming Spreadsheet program
HARBINGER[2] (U.K. 1993)	**Determine** optimal allocation of waste from source to facilities on the basis of least cost **Evaluate** technical performance and cost of options	Linear programming Sensitivity study
GIGO[3] (U.S. 1993)	**Determine** optimal allocation of waste from source to facilities on the basis of least cost **Evaluate** the efficiency and cost of options	Spreadsheet program Sensitivity study Linear programming
SWIM[4] (AUS 1998)	**Evaluate** cost and environmental impacts (CO_2 emissions) of options	Lifecycle assessment technique iThink modelling package
MIMES/WASTE[5] (Sweden 1998)	**Determine** management system at minimum cost **Determine** optimal solution under given conditions **Evaluate** options from viewpoints of technical, economic, and environmental feasibility	Spreadsheet GAMS programming package Lifecycle assessment technique
MADS[6] (2000)	**Evaluate** cost and environmental impacts of options	Lifecycle assessment technique
SWPlan[7] (U.S. 2001)	**Determine** optimal solution under given conditions	WISARD (LCA) Spreadsheet CPLEX (LP), Visual Basic

Source: (1) Ossenbruggen and Ossenbruggen 1992; (2) Pugh 1993; (3) Anex et al. 1996; (4) Wang, Richardson and Roddick 1998; (5) Tanskanen, Reinikainen and Melanen 1998; (6) Ljunggren 2000; (7) Harrison et al. 2001

In summary, MSW management support tools have been developed to assist local authorities in each planning process including (1) technology evaluation and assessment, (2) alternatives formulation, (3) alternatives evaluation, and (4) alternatives selection as shown in Table 2-21.

Table 2-21: Application of reviewed MSW management planning support models

Model	**Application**			
	Technology Assessment	**Strategy Formulation**	**Strategy Assessment**	**Strategy Selection**
SWAP[(1)]		.		
HARBINGER[(2)]	.	.	.	
DSS[(3)]	.	.		
MIMES/Waste[(4)]	.	.	.	
GIGO[(5)]	.		.	
MARKAL[(6)]		.	.	
SWIM[(7)]	.		.	
EUGENE[(8)]	.	.		
ELECTRE[(9)]				.

Source: (1) Ossenbruggen and Ossenbruggen 1992; (2) Pugh 1993; (3) Barlishen and Baetz 1995; (4) Tanskanen, Reinikainen and Melanen 1998; (5) Anex et al. 1996; (6) Gielen 1998; (7) Wang, Richardson and Roddick 1998; (8) Berger et al. 1998; and (9) Hokkanen et al. 1995

Early stage, the planning support tool was developed for technology evaluation. With the increasing capacity and availability of computer facility where complicated analysis can be carried out, MSW management support tools at present are developed for alternatives evaluation and selection applications.

2.8.1. ALTERNATIVE EVALUATION TOOL

As for alternatives evaluation, economic and environmental impacts are common aspects with increasing efforts in social impact evaluation due to growing concern in the concept of sustainable MSW management, which should be economically affordable, environmentally effective and socially acceptable. To evaluate economic aspect, cost-benefit analysis (CBA) is a common technique while life cycle assessment (LCA) is commonly used for environmental impact evaluation. Software package available for LCA are GABI, IWM, SIMA Pro, WARM and WISARD (Morrissey and Browne, 2004). Available performance evaluation softwares at present are WISARD, WASTED, IWM, WARM and ORWARE.

WISARD or Waste Integrated System for Assessment of Recovery and Disposal is developed from U.K. It evaluates environmental impact based on LCA (ISO 14040) and carries out cost benefit analysis. However, WISARD does not giving weight to each environmental impact category, taking social impacts into account and limiting types of treatment facility. **WASTED** or Waste Analysis Software Tool for Environmental Decision model is developed from Canada and provides data on emissions from diesel, gas collection vehicle, and energy used, air Emission, and waste emission from recycling process. WASTED also calculates emission and energy used and saved of each option.

IWM or Integrated Waste Management Model for Municipalities forecasts waste generation (prognostic module) and calculates (assessment module) environmental sustainability (LCIA), economic sustainability (cost and incomes per person) and social sustainability (giving score 0-1 of social impact equitability). **WARM** or Waste Reduction Model is developed by U.S. EPA and calculates total GHG emissions of baseline and alternative waste management practices including source reduction, recycling, combustion, composting, and landfilling. Lastly, **ORWARE** (Organic Waste Research) is developed from Sweden and calculate substances flows, environmental impact and cost.

These tools can be used to enhance the MSW planning capability of local authorities in Thailand. However, it is found that they have been developed from developed countries. The applicability of these tools to developing countries like Thailand is therefore doubtful. Differences in waste characteristics, problem priority, locally available resources and socioeconomic structure may analyse different aspects. Some issues are vital in developing countries but unimportant or less important in developed countries, such as scavenger. Moreover, only a few have involved social impacts evaluation in the model regarding the concept of sustainability. The performances of any options are also evaluated and presented individually (cost, environmental impact, or efficiency).

2.8.2. METHODS FOR ALTERNATIVE SELECTION

As for alternatives selection, multicriteria decision analysis (MCDA) is a common technique used to select the best choice among others. Various MCDA techniques have been developed in recent years that could be applied to MSW management field, such as so called ELECTRE, PROMETHEE, AHP and TOPSIS (Morrissey and Browne, 2004; Hung, Ma and Yang 2007).

Available MCDA softwares are EXPERT CHOICE (AHP), ELECTRE TRI Assistant (ELECTRE III), PROMCALC (PROMETHEE), and HIPRE 3+ (AHP) (Morrissey and Browne, 2004). However, it is suggested that ELECTRE III is the most suitable and most commonly used for MSW management at present (Roy 1990; Karagiannidis and Moussiopoulos 1997; Hokkanen and Salminen 1997; Morrissey and Browne 2004; Norese 2006).

ELECTRE is originated in Europe in the mid-1960's and stands for ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality). It was firstly proposed by Bernard Roy and his colleagues at SEMA Consultancy Company and applied in 1965. The best action(s) from a given set of actions is chosen based on an outranking method. ELECTRE needs little preference information and is capable to deal with imprecise data. The analysis procedure is as follows:

1. Develop alternatives for the problem
2. Define study objectives

3. Define and weigh criteria by experts, supervision group, municipalities' officers through a series of workshops or questionnaires, either put the weight directly or provide relative importance and normalise the weight
4. Determine alternatives performance subjected to selected criteria
5. Determine thresholds
6. Determine concordance and Disconcordance index
7. Determine outranking degree
8. Construct 2 preorders, and
9. Finalise ranking order

ELECTRE was applied to determine appropriate MSW management system in Greater Athens area (Karagiannidis and Moussiopoulos 1997). Five alternatives were evaluated against 24 Criteria, synthesised from Hokkanen and Salminen 1994; Caruso, Colorni and Paruccini 1993; and Skordilis 1992 and commented by competent authorities as summarised in Table 2-22. The analysis illustrated that the 4th alternative was suitable for the Greater Athens area indicating that source separation was more advantageous than relying on material recovery facility.

Another case study of applying ELECTRE method to solid waste problem was in Oulu region, Finland (Hokkanen and Salminen 1997). Twenty two alternatives were formulated and evaluated against 8 criteria, selected by 113 decision makers and supervisory group. The alternatives were various combinations of three technologies including landfill, composting, and RDF combustion. Evaluation criteria were net cost; technical reliability; global effects, local and regional health effects; acidificative releases; surface water dispersed releases; number of employees; and amount of recovered waste.

Table 2-22: Application of ELECTRE in Greater Athens area

Alternatives	Evaluation Criteria
1. Sanitary landfilling in the present landfill 2. Sanitary landfilling in three new landfills 3. Sanitary landfilling in three new landfills, with a material recovery facility in each one and separate collection of paper in all municipalities and communities 4. Sanitary landfilling in three new landfills and separate collection of paper, glass, aluminium and fermentation 5. Incineration in one facility and separate collection of paper, glass and aluminium	1. Politico-social criteria: 1.1 degree of legislation implementation 1.2 use of legislation 1.3 unemployment rate 2. Environmental criteria: 2.1 noise pollution 2.2 air pollution 2.3 soil pollution 2.4 water pollution 2.5 optical pollution (aesthetic) 3. Financial criteria: 3.1 capital cost 3.2 operating cost 3.3 tipping fee 3.4 recyclable market 3.5 financial development in other sector 3.6 utilisation of financing 4. Technological criteria: 4.1 operationality 4.2 sensitivity to waste composition 4.3 new demand adaptability 4.4 operational life 4.5 completion of installation 4.6 reliability of installation 5. Resource-conservation criteria: 5.1 recovered materials 5.2 recovered energy

Weights collected from technical and environmental committee of municipalities by asking them to assign the criteria weight ranging from 1-7, 7 being the most important and to assign number 1 to the least important criterion, and then base the other importance values on how many times more importance than the least important criterion. Final weights were determined on the basis of majority.

These tools are also developed countries and require intensive input data, rarely available in local authorities in Thailand. Applying these tools efficiently is almost impossible. Although this kind of tool evaluates the overall performance, some aspects are determined comparatively among all options considered for the best choice. Moreover, these tools do not determine the overall performance of a single MSW management system.

2.9 CONCLUSION

Sustainable MSW management system means the system that reduces the environmental impacts of MSW from all parts of responsible area to the level that is accepted by the community in terms of operating manner and cost. The objective of sustainable MSW management is to minimise waste going to final disposal by minimising generation rate and maximising recovery rate. Waste must be treated in an environmental friendly manner at all processes. Moreover, sustainable MSW management system should be adaptable to meet changes in waste composition, social-economic structure, and environmental concerns in order to reduce risks to human health or the environment either now or in the future.

Moving towards sustainable MSW management system needs local authorities that can develop a policy and plan giving right direction to achieve the sustainability, enact and enforce regulations needed to implement the policy, provide sufficient infrastructure and budget, and collaborate with other key players particularly public to regulate the system. Regarding their responsibility, local authorities need effective planning and implementation unit. The planning unit develops MSW management plan and policy based on the available budget, technologies, and management capability. MSW management plan provides the implementation unit a working pattern to direct the MSW management system.

The efficiency of the implementation unit thus partly depends on the performance of the planning unit. Therefore, local authorities with effective MSW planning system enhance the chance of achieving sustainable MSW management system, in which the system suited to local conditions including MSW quantity and characteristics; operating skill; budget; and public participation is selected.

This issue, however, has been received little attention compared with implementation process in Thailand. Many local authorities have low capabilities to develop appropriate MSW management system for their areas by themselves although sufficient resources are available. Measures to enhance their planning capabilities are thus required along with other actions in order to improve the status of MSW management in Thailand.

Enhancing the MSW planning capability requires improvements on six key components including planning staff, information management system, decision support system, planning management system, planning supporting facilities, and organisation administrative structure. However, a common action is to use computer-based tool (planning support facilities). Various analysis tools have been developed and widely used to ease the complexity of MSW planning process. Their applications are such as management alternatives formulation, evaluation, and selection.

However, these support tools are mostly invented from the developed countries. It would be difficult for local authorities in Thailand to use them efficiently due to the differences in analysis aspects and difficulty in acquiring input data. Simpler but reasonable analysis tool is more suitable for the case of Thailand. Since knowing the weaknesses of existing MSW management system is an important step in order to select appropriate improvement actions, developing the tool to assist local authorities in assessing their existing MSW management system would be a very useful measure for enhancing their planning capability and consequently MSW management system.

CHAPTER 3

RESEARCH DESIGN

3.1. INTRODUCTION

This chapter presents the research method. The objective of this research is developing a new tool to assist local authorities in Thailand in MSW planning process. Their planning capability can be enhanced. More appropriate actions would consequently be implemented. Improvement on their MSW management system is expected. Since the first planning step is to determine the existing weaknesses, the application of the proposed tool is to assess the performance of current MSW management system subject to the sustainable conditions, common goal for MSW management at present. The output of the proposed tool is a score or number indicating the sustainability level of their current MSW management systems. The gap for achieving sustainable MSW management system is thus revealed. Proper actions to tackle existing problems are expected in the development plan to decrease the gap. There is no MSW planning support tool with such feature available at present.

Taking the sustainable concept into account, efficiency, economic, environmental and social performances of the existing MSW management system were evaluated and combined to provide the overall performance score. Multiple criteria decision analysis (MCDA) technique was thus adopted and adapted to develop the evaluation process. The methodology of this study is as follows.

1. develop the evaluation concept of the proposed assessment tool
2. identify the evaluation aspects of sustainable MSW management system
3. develop methods to score each evaluation aspect
4. develop the method to determine the overall performance or sustainability score of each MSW management system

5. verify the proposed evaluation methods, and
6. develop the proposed assessment tool in a form of a computer-based tool

The details of each research step are described in the following sections.

3.2. THE EVALUATION CONCEPT OF THE PROPOSED ASSESSMENT TOOL

Based on the literature review in Chapter 2, a common definition of sustainable MSW management system is the system that should be environmentally effective, economically affordable, and socially acceptable. However, ***sustainable MSW management*** for this study refers to "the system that should be ***Sufficient, Continuous, and Sanitary for Long term*** and can be managed with ***available local knowledge, resources and wisdom*"**. In order to achieve such system, the following six factors are needed:

1. local authorities that are able to plan and implement accordingly and collaborate with other stakeholders
2. sufficient budget for capital, operating and maintenance cost
3. sufficient area and technologies that can be handled locally
4. policies and plans that support sustainable concepts
5. law or regulation that enhance the cooperation
6. public that are aware and want to participate in problem solving process

The relationship of these factors (Figure 2-7 in Chapter 2) illustrated that sophisticate MSW management system cannot be working without supports from local authorities in terms of management capability and from the public in terms of willingness to participate in regulating the system. Vice versa, effective local authorities with high public participation need effective technologies compatible with their capability to achieve the sustainability.

Therefore, the proposed assessment tool evaluates the performance of ***four key components*** including; the engineering system (ES), the local authority's capability (LAC), the public participation (PP), and their collaboration (CB) as summarised in Figure 3-1 in order to check the sustainability of current MSW management system. Environmental, economic, and social aspects are included in these four components.

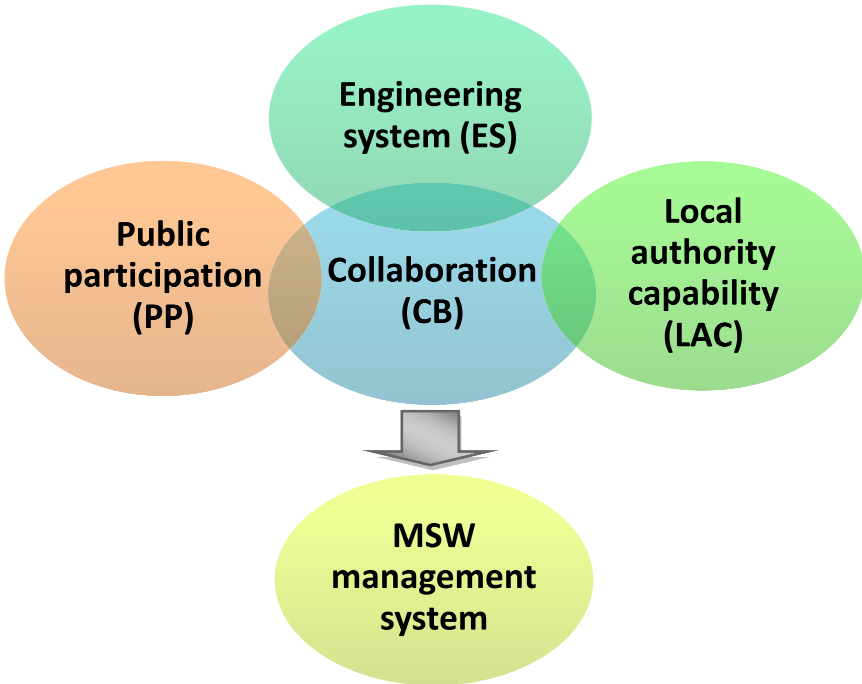


Figure 3-1: The evaluation components of the proposed assessment tool

The score of each evaluation component was calculated and combined to determine the overall score indicating the sustainability level. The evaluation step of the proposed assessment tool is shown in Figure 3-2. The targeted users of the proposed assessment tool are local staff responsible for regulating MSW management system.

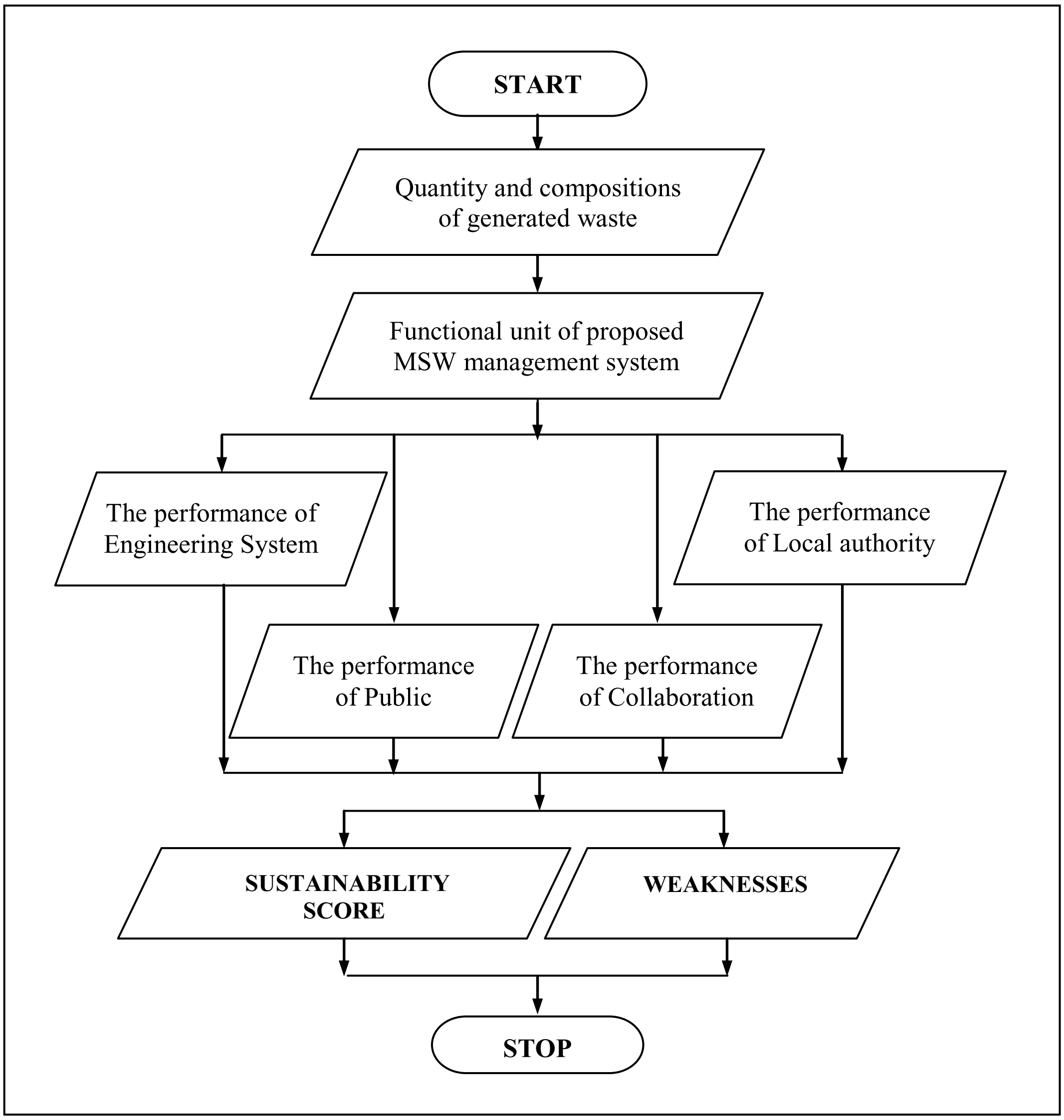


Figure 3-2: Structure of the proposed assessment tool

3.3. THE DEVELOPEMNT OF EVALUATION ASPECTS

Each evaluation component consists of a number of evaluation aspects. It is important to note that these evaluation aspects were selected considering the ability of local authorities to acquire the input data. The details are as follows.

3.3.1. ENGINEERING SYSTEM (ES)

From the literature reviewed in Chapter 2 (Figure 2-2) and the characteristics defined for this research, sustainable MSW management system must achieve the following conditions, from the engineering point of view:

1. all generated waste is stored
2. all generated waste is collected
3. processing technologies is suitable to waste characteristics
4. sufficient land area is available for final disposal
5. disposal area is sanitary, and
6. environmental impact is at acceptable level

Final disposal site is commonly designed for waste that will be generated in the next 15 or 20 years. The period is also considered sufficient to ensure the complete degradation of organic substances. The landfill mining process can be conducted to recover the space and expand its lifespan.

Accordingly, the evaluation aspects of the engineering system component are:

1. the storage capacity
2. the collection efficiency
3. the processing technologies suitability
4. the lifespan of available disposal area
5. the availability of sanitary landfill, and
6. the environmental impact

Environmental aspect is included in this evaluation component. The performance of source reduction activity is indirectly evaluated through the lifespan of available disposal land area due to the difficulty in measuring directly as it is related to the public's behavior.

3.3.2. LOCAL AUTHORITIES CAPABILITY (LAC)

As discussed in Chapter 2 (section 2.6.1), the planning and implementation capabilities of local authority are crucial to achieve sustainable MSW management system. The planning unit must develop MSW management plan addressing the details of MSW management system that meet its local needs while the implementation unit brings the developed management plan into effect and regulates the system to achieve its goals. Although having good plans does not guarantee good operating systems, the chances of achieving them are higher.

Fundamentally, local authorities need effective MSW planning system and must efficiently utilize the available planning system. Once the proper MSW management system is designed, sufficient budget plays an important role to construct the designed MSW system (capital cost) and to operate the management system as planned (operating cost). Ideally, operating cost should cover actual cost in order to sustain the performance of MSW management system. Another aspect that affects the implementation performance is the problem priority. Sufficient resources and attention is always given to high priority problem.

In summary, the evaluation aspects of the local authorities' capability component are;

1. the effectiveness of planning system
2. the efficiency of planning system
3. the budget availability, and
4. the problem priority

The economic aspect is included in this evaluation component.

3.3.3. PUBLIC PARTICIPATION (PP)

Social aspect is analysed in this component. As discussed earlier, achieving sustainable MSW management system requires the supports from the public. This includes not only the community but also private company, manufacturer, academics, or NGOs (Figure 2-11 – Chapter 2). Role of the public can be divided into two sides: providers and users. However, this component only concerns the role of the public as a user of the MSW management system provided by local authority.

The experiences of various countries illustrated that achieving sustainable MSW management basically requires the public that see the significance of MSW and is willing to participate in separation program and to pay the service fee. With the right attitude, high participation in waste management campaign can be subsequently expected. Thus, the evaluation aspects of this evaluation component are:

1. the public awareness, and
2. the public willingness

3.3.4. COLLABORATION (CB)

Although sophisticate technologies, effective local authorities, and high public awareness are available in the area, sustainable MSW management system cannot be achieved if these three components are not working together. Highly efficient technologies will be eventually shut down if only local authority want to implement while the public do not, and vice versa. Therefore, the forth evaluation component of the proposed assessment tool is the collaboration among the key stakeholders.

Since local authorities are directly responsible for MSW management, they should take the lead or encourage the collaboration. Local authority should express their intention by allowing the public to participate in the management process as part of service provider. Many waste management activities at present should be operated at source to increase the efficiency such as separation or composting. Collaboration from the residences for these activities is significant. Local authority should also involve waste picker or scavenger in the process as recovery service provider. Besides implementation process, the public should be allowed to participate in planning process such as public hearing process.

The public should then involve themselves in these processes to ensure that the implemented management system is working properly. Besides the collaboration with the public, local authorities must also work with technologies. They must be capable of regulating the implemented technologies by themselves in order to sustain the performance. Many cases, the facilities were shut down after the external supporters left.

Therefore, the evaluation aspects of this component include:

1. the collaboration encouragement
2. the planning process collaboration
3. the implementation process collaboration
4. the technical collaboration

In summary, the proposed assessment tool evaluates four main components containing 16 evaluation aspects as shown in Table 3-1.

Table 3-1: Evaluation aspects of the proposed assessment tool

Evaluation Components	**Evaluation Aspects**	**Code**
Engineering System (ES)	∉ Storage capacity	E1
	∉ Collection efficiency	E2
	∉ Processing technologies efficiency	E3
	∉ Lifespan of available disposal area	E4
	∉ Availability of sanitary landfill	E5
	∉ Environmental impact	E6
Local authorities' Capability (LAC)	∉ Planning system effectiveness	L1
	∉ Planning system efficiency	L2
	∉ Budget availability	L3
	∉ Problem priority	L4
Public Participation (PP)	∉ Public awareness	P1
	∉ Public willingness	P2
Collaboration (CB)	∉ Collaboration encouragement	C1
	∉ Planning process collaboration	C2
	∉ Implementation process collaboration	C3
	∉ Technical collaboration	C4

3.4. THE MEASUREMENT METHODS OF EVALUATION ASPECTS

The methods used to calculate the score of each evaluation aspect were both adopted from available formulas and newly developed. As mentioned earlier, the calculation method for each evaluation aspect was selected or developed concerning the actual conditions practically and the ability of local authority to acquire the input data. Simplified evaluation is thus necessary. However, the analysis output must reasonably illustrate the sustainability level of MSW management system.

3.4.1. ENGINEERING SYSTEM (ES)

Available mathematical equations in the field of solid waste engineering were adopted to calculate the evaluation aspect E1 (storage), E2 (collection) and E4 (landfill lifespan). Meanwhile, available Thai standards regarding MSW management activities were adopted to develop new evaluation methods for the evaluation aspect E3 (processing technology), E5 (sanitary landfill) and E6 (environmental impact).

3.4.2. LOCAL AUTHORITIES CAPABILITY (LAC)

At present, there is no mathematical equation or standards that can be applied to evaluate the effectiveness and efficiency of MSW planning system (L1 and L2 respectively). Thus, a new mathematical equation was developed for this research to measure the performance of MSW planning system of any local authority because this aspect was mentioned in Table 2-7 (Chapter 2) as the most important factor for MSW management.

Based on the literature in Section 2.7.3 (Chapter 2), the effectiveness of MSW planning system depends on the following components:

1. planning staff (PS)
2. planning support system (PSS)
3. decision support system (DSS)
4. information management system (IMS)
5. planning management system (PMS), and
6. organisation's administrative structure (AS)

Appropriate conditions of these planning components for effective MSW planning system are summarized in Table 3-2.

Table 3-2: Appropriate conditions of each planning component

Component	Appropriate Conditions
Planning Staff (PS)	∉ Planning staff should be available for the planning activities
Planning Support System (PSS)	∉ Training program for improving knowledge of corresponding staff are available ∉ Instruction for performing their task are provided prior to the planning process ∉ Budget for running the planning activities, training corresponding staff, and acquiring planning facilities are available ∉ Facilities/materials for assisting corresponding staff are available
Decision Support Subsystem (DSS)	∉ Detail of the performance of existing operational management system and the possible alternatives are available for planning process ∉ Criteria used to evaluate the possible alternatives are performance, economic, environmental impact and social impacts ∉ Computer-based analytical tool is used in the process ∉ Meeting and public hearing are held before final decision
Information Management System (IMS)	∉ Fundamental data/ information for planning activities is available ∉ Available data/ information is accessible by relevant staff when needed and kept in useful format
Planning Management System (PMS)	∉ The detail of planning procedure, information management manner, decision making manner, and plan management manner are documented and available for planning staff
Administrative System (AS)	∉ Administrative system are supportive to planning activities by allowing planning staff to focus on their planning task and continuity of the process

These six planning components were then evaluated to check the effectiveness of MSW planning system of any local authorities. The effectiveness score of MSW planning system was set to equal the summation of each planning component score as follows:

$$\boldsymbol{Planning\ Effectiveness\ Score = PS + PSS + DSS + IMS + PMS + AS}$$

The score for each planning component was divided into three levels according to their performance including Good (G), Fair (F) and Poor (P) as described in Table 3-3 (Sakulrat 2006; Sakulrat and Darnsawasdi 2009). Good performance is obtained when the conditions in Table 3-2 are achieved. The full score of each performance level for each planning component was established according to its significance to the overall performance of the MSW planning system.

To determine the planning efficiency, the output of MSW planning system was evaluated. At present, proper MSW planning system in Thailand should produce MSW management plan in three formats including strategy, project/program plan (3 years plan), and day-to-day operating plan. The strategy contains information about the overall structure of the MSW management system from sources to final disposal. Project/programs then deal with individual objectives addressed in the strategy such as technical parameters of each management process (Tchobanoglous, Theisen and Eliassen 1977; King and Cleland 1978). A day-to-day operating plan provides the precise instructions needed to implement each management process, such as a collection route and schedule.

The efficiency of MSW planning system was consequently determined by comparing the types of MSW management plans that are actually produced with the types of MSW management plans that should be produced according to the available planning resources or planning system effectiveness.

Table 3-3: Performance level descriptions of each planning component

Component	**Performance Level**		
	Good (G)	**Fair (F)**	**Poor (P)**
Planning Staff (PS)	More than one planning staff are available	Only one planning staff is available	Planning staff not available
Planning Supporting System (PSS)	Planning budget, facilities, training are available	Either planning budgets, facilities, or training are not available	Planning budget, facilities, and training are not available
Decision support system (DSS)	Decision-making data and decision-supporting tool are available. Brainstorming and public hearings take place.	Either decision making data or decision support tool or formal meetings are not available	Decision making data and decision support tool is not available
Information management system (IMS)	Necessary data are available and properly stored	Some necessary data are not available or available data are not properly stored	Few necessary data are available or available data are not properly stored
Planning management system (PLMS)	All information for planning activities are available and conveniently accessed	Some information for planning activities are unavailable or not conveniently accessed	Little information for planning activities are available or not conveniently accessed
Administrative system (AS)	Administrative system is considered supportive	-	Administrative system is considered unsupportive

To determine the significance of each planning component and the types of MSW management plans that should be produced, questionnaires were sent to local authorities in Thailand to collect data. The questionnaire was adopted from Sakulrat (2006) collecting the following data: (1) the general background of studied local authorities; (2) the performance of MSW management system; (3) planning procedure; (4) the conditions of six planning components; and (5) planning output. The detail of questionnaire is given in Appendix A. The questionnaire was tested with few local authorities before distribution.

Regarding the research scope, only four forms of local authorities are studied. In 2007, there were 23 Nakhon municipalities, 129 Muang municipalities, 1,124 Tambon municipalities, 6,500 Tambon administrative organisation (DOLA 2007). However, the study focused on local authorities responsible for the area producing large amount of MSW in which appropriate MSW management system is incredibly important. All Nakhon municipalities were thus included.

According to the national goal, the area producing MSW more than 1 kg/cap/day was classified in this research as the large waste producer. Based on the Pollution Control Department's 2003 database, the majority of the municipalities generated MSW more than 1 kg/cap/day has population density greater than 600 per square kilometre and has revenue of more than 7 million Baht. These criteria were used for this research to select local authorities in other forms that were expected to produce the large amount of MSW. The number of each local authority's form that meets these criteria is summarized in Table 3-4. The questionnaire was thus sent out to 884 local authorities from all regions of the country.

Table 3-4: The number of targeted local authorities by forms

Form of Local Government	**Total**	**Target**	**Region**				
			North	**North East**	**Central**	**East**	**South**
Nakhon Municipality	23	23	3	5	10	0	5
Muang Municipality	129	113	10	28	44	11	20
Tambon Municipality	1,124	544	82	187	167	29	79
Tambon Administrative Organisation	6,500	204	31	20	126	8	19
Total	**7,776**	**884**	**126**	**240**	**347**	**48**	**123**

From 884 questionnaires sent out, 347 of them returned giving about 40% response rate as summarised in Table 3-5. As expected, Nakhon municipality as a top level has the highest rate of return while TAOs, the lowest level, has the lowest rate of return. The staff answered the questionnaire are from three departments including the Public Health and Environment division, the Public Works division, and the Administrative Office.

Table 3-5: Number of local authorities in Thailand that returned the questionnaire

Form of Local Authority	**Number of Local authorities**		
	Targeted	**Returned**	**Return Rate**
Nakhon Municipality	23	13	57%
Muang Municipality	113	34	30%
Tambon Municipality	544	242	44%
Tambon Administration Organisation	204	58	28%
Total	**884**	**347**	**40%**

However, the 347 returned questionnaires account for 90% of the required sample based on Taro Yamane formula as shown below, where the level of precision is equal to 5%. Therefore, the result from the collected questionnaires was reliable.

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

$$n = \frac{7{,}776}{1 + 7{,}776(0.05)^2} = 380$$

The collected data were firstly evaluated to define the performance level subject to the descriptions in Table 3-3 and subsequently to divide MSW planning systems into five groups including the MSW planning systems that;

Group 1: did not produce any MSW management plan,

Group 2: produced only operating or program plan,

Group 3: produced both operating and program plans,

Group 4: produced operating plan, program plan, and strategy or long term plan, and

Group 5: produced operating plan, program plan and strategy or long term plan containing all necessary information.

Next, the common characteristics of each group were evaluated to identify the conditions that produce each planning output characteristic and also the significance of each planning component on the planning output. The score of each planning component at each performance level was consequently determined. Besides knowing the significance of each component, the findings are also useful for developing a proper, step-by-step strategy for improving current MSW planning capability at the local level in Thailand. It might be difficult for some local authorities to achieve comprehensive planning systems at first. Thus, knowing the fundamental requirements for starting and upgrading the system is helpful.

Moreover, the conditions that produced each planning output were illustrated, which can be used to determine the types of MSW management plans that this local authority should be able to produce based on the performance of those six planning components.

3.4.3. PUBLIC PARTICIPATION (PP)

This component evaluates the attitude of the public towards MSW management system. Since no mathematical model is available for evaluating this component, simple scoring methods were developed to evaluate the public participation performance. Common activities intrinsically illustrated the public awareness (P1) and public willingness (P2) were compiled and checked by asking local staff directly responsible for MSW management in the area.

3.4.4. COLLABORATION (CB)

Mathematical model is also not available for evaluating this component. Similar to the Public Participation component, simple scoring method was used to determine the collaboration between local authorities, public, and technologies in MSW management. The fundamental activities indicating the collaboration encouragement (C1), the collaboration between local authority and public in planning process (C2), the collaboration between local authority and public in implementation process (C3), and the collaboration between local authority and technologies were also gathered and checked by asking local authority.

3.5. THE CALCULATION OF THE SUSTAINABILITY SCORE

The overall performance score or the sustainability score of any MSW management system was equal to the summation of each evaluation component's score as follows.

$$Sustainability\ score = ES + LAC + PP + CB$$

Where ES = Engineering system score

LAC = Local authorities' capability score

PP = Public participation score

CB = Collaboration score

The score of each evaluation component was equal to the summation of its evaluation aspects' score as presented in Table 3-1. In total, there were 16 evaluation aspects. The full score of each evaluation aspect was set to equal to 1. However, weights were assigned to each evaluation aspect and each evaluation component before the sustainability score was calculated. The calculation table is as illustrated in Table 3-6

Table 3-6: Sustainability score calculation table

Evaluation Components	**Evaluation Aspects**	**Evaluated score**	**Aspect Weight**	**Component Weight**	**Component score**
Engineering System (ES)	E1				
	E2				
	E3				
	E4				
	E5				
	E6				
Local authorities' Capability (LAC)	L1				
	L2				
	L3				
	L4				
Public Participation (PP)	P1				
	P2				
Collaboration (CB)	C1				
	C2				
	C3				
	C4				
				Sustainability Score	

Weights of each evaluation aspect and component were assigned based on its significance to the efficiency of MSW management system found in the literature review – Chapter 2.

3.6. THE VERIFICATION OF EVALUTION METHODS

The proposed evaluation methods, both calculation methods and weights were subsequently verified. In doing so, the data on MSW management of local authorities in Thailand was collected again. The second questionnaire was developed to collect the data as shown in Table 3-7, divided into 5 sections.

Table 3-7: The data obtained from the second questionnaire

Section	Detail of collected data
1	∉ Form of local authority ∉ Size of responsible area ∉ Size of population both registered and non-registered ∉ Population growth rate
2	∉ Quantity of waste generated each day ∉ Composition of generated waste
3	∉ Stakeholders in MSW management activities
4	∉ Current performance of source separation, storage, collection, processing and disposal activities ∉ Budget for MSW management ∉ Current problem of their MSW management
5	∉ Current performance of their planning system ∉ Overall performance of their current MSW management

The second questionnaire was given to 71 local authorities from southern provinces of Thailand who attended solid waste lecture given by the author. All four forms of local authority were included as shown in Table 3-8.

Table 3-8: Number of local authorities studied for verifying the proposed assessment tool

Form of Local authority	Number of Local authorities
Nakhon municipality (NM)	2
Muang municipality (MM)	5
Tambon municipality (TM)	15
Tambon administrative organization (TAO)	49
Total	**71**

Local authorities were also asked to rate the performance level of their current MSW management system in the questionnaire. The performance level is classified into six levels as described in Table 3-9.

Table 3-9: Performance level of MSW management system

Performance Level	Description
0	No system is in place
1	System is in place, but not sufficient
2	System is in place, sufficient, but not regular
3	System is in place, sufficient, regular, but not environmentally friendly
4	System is in place, sufficient, regular, environmentally friendly, but not sustainable
5	System is in place, sufficient, regular, environmentally friendly, and sustainable

The collected data was analysed to calculate the overall performance score or the sustainability scores of their existing MSW management systems. The calculated score was subsequently linked to its performance level indicated by local authorities in the questionnaire. The analysis rationale was that the higher overall performance score, the higher performance level of MSW management system. In case the result was not reasonably correlated, the proposed evaluation methods were adjusted. Applications to few local authorities were finally discussed.

3.7. THE DEVELOPMENT OF THE PROPOSED ASSESSMENT TOOL

Once the evaluation methods were satisfied, the proposed assessment tool was subsequently developed in **Excel Spreadsheet** format as it is simple to use and local authorities should be familiar with. It contains 11 worksheets. The first two worksheets are input interface. Worksheet 1 receives data to determine the score of the Engineering System (ES), the Public Participation (PP), and the Collaboration (CB) components while Worksheet 2 receives data to determine the score of the Local authorities' capability (LAC) component. These input data from both worksheets were used to calculate the score of all 16 evaluation aspects using the developed evaluation methods.

Worksheet 3 calculates the waste quantity. Worksheet 4 to 8 evaluates the storage capacity (E1), the collection efficiency (E2), processing technologies efficiency (E3); disposal area lifespan and the availability of sanitary landfill characteristics (E4, E5); and environmental impact (E6) respectively. Worksheet 9 determines the level of public participation (P1, P2) while worksheet 10 evaluates the collaboration (C1, C2, C3, C4). The overall performance score or the sustainability score (Table 3-6) was finally calculated and demonstrated to the user in worksheet 11. Thus, the user will only see worksheet 1,2 and 11 of the developed assessment tool.

CHAPTER 4

RESEARCH RESULT

THE DEVELOPMENT OF THE ASSESSMENT TOOL

4.1. INTRODUCTION

This chapter presents the research output or the methods developed for the proposed assessment tool to calculate the score of each evaluation aspects and the sustainability score of current MSW management systems. The detail of the proposed assessment tool is also presented. According to the research method presented in Chapter 3, the proposed assessment tool evaluates four main components of MSW management system significantly contributing to the sustainability of MSW management system. These four evaluation components are the Engineering system, Local authority's capability, Public participation, and Collaboration.

Each evaluation component consists of a number of evaluation aspects. The final output of the proposed assessment tool is a score or number indicating the sustainability level of analysed MSW management, in which MSW management system with higher score would have a higher potential of achieving the sustainable goal. The assumptions that were used to develop all these score calculation methods are explained along with the calculation examples.

The verification result of the proposed evaluation methods is subsequently illustrated. The reliability of the proposed assessment tool is discussed as well as the current performance of MSW planning systems of local authorities in Thailand and the significance of the support tool to ensure the benefit of providing a new MSW assessment tool to improve MSW management system.

4.2. THE DEVELOPMENT OF EVALUATION METHODS

Methods to calculate the score of those 16 evaluation aspects presented in Table 3-1 (Chapter 3) are illustrated in this section. These methods were developed considering mainly on the limitation of local authorities to acquire input data and actual practices. The full score of each evaluation aspect is set to equal to 1, which can be obtained when its appropriate condition for sustainable MSW management system listed in Table 4-1 is achieved. These conditions are obtained from the experiences of various countries found in Chapter 2.

Table 4-1: The appropriate conditions of evaluation aspects

Evaluation Components	Evaluation Aspect	Appropriate Conditions
Engineering System (ES)	E1	∉ all generated waste is stored
	E2	∉ all generated waste is collected
	E3	∉ processing technologies is suitable to waste characteristics
	E4	∉ sufficient land area is available for final disposal
	E5	∉ disposal area is sanitary
	E6	∉ environmental impact is at acceptable level
Local authorities' Capability (LAC)	L1	∉ effective MSW planning system is available
	L2	∉ available MSW planning system is efficient
	L3	∉ annual operating budget is sufficient
	L4	∉ MSW problem is priority
Public Participation (PP)	P1	∉ public sees the significance of MSW
	P2	∉ public participates in MSW related activities
Collaboration (CB)	C1	∉ local authority encourages public to participate in MSW system
	C2	∉ public involves themselves in MSW planning process of local authority
	C3	∉ public involves themselves in MSW implementation process
	C4	∉ local authorities can handle the implemented management technologies

4.2.1. THE ENGINEERING SYSTEM COMPONENT (ES)

Well-developed mathematical equations in the field of solid waste engineering and available standards and criteria were adopted to evaluate the performance of the engineering system component. The details are described in the following sections.

4.2.1.1. Storage Capacity (E1)

This aspect checks whether the number of provided containers is sufficient for storing the generated waste. The storage capacity is calculated as:

$$\boldsymbol{E1} = \frac{\boldsymbol{Total\ container\ volume}\ (\boldsymbol{m^3})}{\boldsymbol{Total\ generated\ waste\ volume}\ (\boldsymbol{m^3})}$$

where the total container volume is equal to the summation of each container size's volume or:

$$\boldsymbol{Total\ container\ volume}\ (\boldsymbol{m^3}) = \sum_{\boldsymbol{i=0}}^{\boldsymbol{n}} (\boldsymbol{size\ of\ container_i\ x\ No.of\ container_i})\ (\boldsymbol{m^3})$$

and the total generated waste volume is equal to

$$\boldsymbol{Total\ generated\ waste\ volume}\ (\boldsymbol{m^3}) = \boldsymbol{Generated\ waste\ volume\ each\ day} \left(\frac{\boldsymbol{m^3}}{\boldsymbol{day}}\right) \boldsymbol{x\ storage\ day}\ (\boldsymbol{days}) + \boldsymbol{uncollected\ waste\ volume\ on\ the\ last\ collection\ day}\ (\boldsymbol{m^3})$$

The generated waste volume each day is equal to:

$$\boldsymbol{Generated\ waste\ volume\ each\ day}\left(\frac{\boldsymbol{m}^3}{\boldsymbol{day}}\right) = \frac{\boldsymbol{Generated\ waste\ quantity}\ (\frac{\boldsymbol{kg}}{\boldsymbol{day}})}{\boldsymbol{Waste\ density}\ (\frac{\boldsymbol{kg}}{\boldsymbol{m}^3})}$$

$$\boldsymbol{Uncollected\ waste\ volume}\ (\boldsymbol{m}^3)$$
$$= [\boldsymbol{Generated\ waste\ volume\ each\ day}\left(\frac{\boldsymbol{m}^3}{\boldsymbol{day}}\right)\ \boldsymbol{x\ storage\ day}\ (\boldsymbol{days})]$$
$$\boldsymbol{x}\ (\boldsymbol{100} - \boldsymbol{Collection\ efficiency}\ \%)$$

In case the waste density of the local authority is not available, the default value of 250 kg/m^3 is used, according to the information from World Bank as shown in Table 4-2.

Table 4-2: Waste density of each economic group

Country	**Waste Density (kg/m^3)**
Industrialised countries	
United States	100
United Kingdom	150
Middle-Income countries	
Singapore	175
Tunisia	175
Nigeria	250
Low-Income countries	
Thailand	250
Indonesia	250
Pakistan	500

Source: World Bank 1999

The storage days depends on the collection frequency. For example, if the collection frequency is three times per week, waste is collected on the 1st, 3rd, and

7^{th} day of the week. Thus, waste is accumulated for 2, 2 and 3 days between each collection day. The maximum storage days is used (3 days for this case) is used to check the sufficiency of provided container. The number of storage days of each collection frequency is summarised in Table 4-3.

Table 4-3: The maximum storage day of each collection frequency

Collection Frequency (times/week)	**Collection date of the week (as indicated in circle)**	**Maximum storage day (days)**
1	(1) 2 3 4 5 6 7	7
2	(1) 2 3 (4) 5 6 7	4
3	(1) 2 (3) 4 (5) 6 7	3
4	(1) 2 (3) 4 (5) 6 (7)	2
5	(1) 2 (3) 4 (5) (6) (7)	2
6	(1) 2 (3) (4) (5) (6) (7)	2
7	(1) (2) (3) (4) (5) (6) (7)	1

Regarding the condition in Table 4-1, **E1** is equal to 1 when the total container volume is at least equal or more than the total volume of MSW to be stored in the community during each collection day. For example, the storage capacity (E1) of local authority **A**, having the conditions listed in Table 4-4 can be calculated as:

Table 4-4: Input data for storage capacity assessment

Parameters	**Input data**
Generated waste quantity	16 tons/day
Waste density	250 kg/m^3
Collection frequency	7 times/week
Number of provided containers	500 containers
Container size	200 liters
Collection efficiency	60%

$$\boldsymbol{Total\ container\ volume\ (m^3)}$$

$$= \frac{\mathbf{200}\ \boldsymbol{liters\ x}\ \mathbf{500}\ \boldsymbol{containers}}{\mathbf{1000}\ \frac{\boldsymbol{liters}}{\boldsymbol{m^3}}} = \mathbf{100}\ \boldsymbol{m^3}$$

$$\boldsymbol{Generated\ waste\ volume\ each\ day}\ \left(\frac{\boldsymbol{m^3}}{\boldsymbol{day}}\right)$$

$$= \frac{\mathbf{16}\frac{\boldsymbol{tons}}{\boldsymbol{day}}\ \boldsymbol{x}\ \mathbf{1000}\frac{\boldsymbol{kg}}{\boldsymbol{ton}}}{\mathbf{250}\ \frac{\boldsymbol{kg}}{\boldsymbol{m^3}}} = \mathbf{64}\ \frac{\boldsymbol{m^3}}{\boldsymbol{day}}$$

$$\boldsymbol{Total\ generated\ waste\ volume\ (m^3)}$$

$$= \mathbf{64}\ \frac{\boldsymbol{m^3}}{\boldsymbol{day}}\boldsymbol{x}\ \mathbf{1}\ \boldsymbol{day}^{*} + \mathbf{64}\ \frac{\boldsymbol{m^3}}{\boldsymbol{day}}\boldsymbol{x}\ \mathbf{1}\ \boldsymbol{day}^{*}\boldsymbol{x}\ \left(\frac{\mathbf{100-60}}{\mathbf{100}}\right)$$

$$= \mathbf{89.6}\ \boldsymbol{m^3}$$

* the number of storage days is equal to 1 (Table 4-3) for the collection frequency 7 times/week

Thus;

$$\boldsymbol{Storage\ capacity\ (E1)} = \frac{\mathbf{100}\ \boldsymbol{m^3}}{\mathbf{89.6}\ \boldsymbol{m^3}} = \mathbf{1.12} = \mathbf{1}\ \boldsymbol{point}$$

It means the number of provided containers is insufficient for total generated MSW.

4.2.1.2. Collection Efficiency (E2)

Similar to the storage capacity, the sufficiency of collection vehicle for all generated waste is checked. The collection efficiency is calculated as:

$$E2 = \frac{\textbf{Total collection truck volume } (\frac{m^3}{day})}{\textbf{Total generated waste volume } (\frac{m^3}{day})}$$

Where;

$$\textbf{Total collection truck volume} \left(\frac{m^3}{day}\right)$$
$$= \sum_{i=0}^{n} (No.of\ Trucks_i\ x\ size\ of\ truck_i\ x\ No.of\ trips_i)$$

Similarly, **E2** is equal to 1 when the total collection truck volume is equal or higher than the total generated waste volume. The data in Table 4-5 illustrates that this local authority has 2 side loading trucks size 3 m^3, which collect 2 and 3 trips per day respectively. There are 3 compaction trucks size 10 m^3. Each collects 1 trip per day.

Table 4-5: Input data for collection efficiency assessment

Parameters	Input data
Generated waste volume	73.6 m^3/day
Number of collection truck	5 trucks
Collection truck size	2@ 3 m^3 side loading / 3@10 m^3 compaction
Collection trip of each truck	2,3 / 1,1,1 trips/day

Thus, **E2** is equal to:

$$\textbf{Total collection truck volume} \left(\frac{m^3}{day}\right)$$
$$= \textbf{Volume of side loading trucks} + \textbf{Volume of compaction trucks}$$

$$\boldsymbol{Volume\ of\ side\ loading\ truck_1} = \left(3\frac{m^3}{trip}\right) x\ 1\ truck\ x\ 2\frac{trips}{day} = 6\ \frac{m^3}{day}$$

$$\boldsymbol{Volume\ of\ side\ loading\ truck_2} = \left(3\frac{m^3}{trip}\right) x\ 1\ truck\ x\ 3\frac{trips}{day} = 9\frac{m^3}{day}$$

$$\boldsymbol{Volume\ of\ compaction\ truck} = \left(10\frac{m^3}{trip}\right) x\ 3\ trucks\ x\ 1\frac{trip}{day} = 30\ \frac{m^3}{day}$$

Thus;

$$\boldsymbol{Total\ collection\ truck\ volume} = 6 + 9 + 30 = 45\ \frac{m^3}{day}$$

$$\boldsymbol{Total\ generated\ waste\ volume} = 73.6\frac{m^3}{day}$$

As a result;

$$\boldsymbol{Collection\ Efficiency\ (E2)} = \frac{45\frac{m^3}{day}}{73.6\frac{m^3}{day}} = 0.61\ point$$

It means the collection trucks and collection frequency are insufficient for total generated MSW.

4.2.1.3. Processing Technologies Efficiency (E3)

In case, the collected waste is formally processed to reduce the amount of waste going to final disposal or landfill, the efficiencies of processing technologies are checked. Common problems of processing technologies are the quantity of incoming waste is larger or smaller than the designed capacity or the characteristics of incoming waste is not compatible with processing technologies resulting in the cost-ineffectiveness and eventually facilities shutdown.

Thus, when central processing facilities are being operated by local authorities, the capacity sufficiency of selected processing technologies to the quantity of incoming waste is firstly checked. The capacity of processing technology should be sufficient for total quantity of incoming waste. Its suitability to the characteristics of incoming waste is subsequently checked. The quantity of incoming waste is finally compared with the quantity of potential recoverable waste. The proportion should be maximized in order to minimise the amount of MSW going to final disposal.

As a result, three aspects are evaluated to check the efficiency of implemented MSW processing technologies including:

1. the sufficiency to waste quantity
2. the suitability to waste characteristics, and
3. the proportion of incoming waste quantity to recoverable waste quantity

Therefore;

$$\boldsymbol{E3} = \boldsymbol{Capacity\ sufficiency\ x\ Characteristic\ suitability\ x\ Recovered\ proportion}$$

where;

$$\boldsymbol{Capacity\ sufficiency} = \frac{\boldsymbol{Total\ quantity\ of\ incoming\ waste\ (\frac{tons}{day})}}{\boldsymbol{Total\ capacity\ of\ implemented\ processing\ technologies\ \left(\frac{tons}{day}\right)}}$$

To check the suitability of implemented processing technologies to the characteristics of incoming waste, new evaluation criteria were developed. Available MSW processing technologies in Thailand at present are composting, material recovery facility (MRF), refuse derived fuel (RDF), anaerobic digestion (AD), and incineration. However, RDF and AD for MSW are under the development process. Moreover, materials are mostly recovered by informal group, not local authorities.

Various recommendations related to MSW processing technologies are available. Guidelines for selecting appropriate MSW processing technologies from Ministry of Energy or Ministry of Natural Resources and Environment are presented in Table 4-6 and Table 4-7 respectively. These guidelines were adopted to check the effectiveness of processing facilities to incoming waste.

Table 4-6: Guideline for selecting processing technologies by Ministry of Energy

Waste Quantity	**Recommended Technologies**
>100 tons/day	Incinerator/ Gasifier/ Pyrolysis
50-100 tons/day	AD + RDF
10-50 tons/day	AD + RDF
5-10 tons/day	AD + RDF
<5 tons/day	Small AD + RDF

Source: Department of Alternative Energy Development and Efficiency 2010

Table 4-7: Guideline for selecting processing technologies by Ministry of Natural Resources and Environment

Cluster size	Recommended Processing Technologies
1. Large Cluster (MSW > 500 tons/day)	MRF + Biological process + Incinerator
2. Medium Cluster (MSW 250 – 500 tons/day)	MRF + Biological process + RDF/Incinerator
3. Medium Cluster 2 (MSW 100 – 250 tons/day)	MRF + Biological process + RDF
4. Medium Cluster 3 (MSW 50 – 100 tons/day)	MRF + Biological process + RDF
5. Small Cluster (MSW < 50 tons/day)	MRF + Biological process

Source: PCD 2010

Additional guideline from Pollution Control Department is given in Table 4-8 based on the cost-benefit consideration.

Table 4-8: Guideline for selecting processing technologies

Criteria	Recommended MSW Processing Technologies
Organic waste < 50 tons/day (cost-effective)	Composting
Total waste >200 tons/day (cost-effective)	Incineration
5-100 tons/day	RDF
Organic waste < 5 tons/day, 5-100 tons/day, Organic waste >60 tons/day (cost effective)	AD

Source: PCD 2010

Based on these available guidelines, the proper MSW processing technologies to each waste characteristic used in the proposed assessment tool are summarised in Table 4-9.

Table 4-9: Adapted guideline for evaluating implemented MSW processing technologies

Evaluation Criteria	**Recommended MSW Processing Technologies**
Organic waste < 50 tons/day and total quantity < 50 tons/day	MRF + Composting + RDF
Organic waste < 50 tons/day and total quantity > 50 tons/day	MRF + Composting + RDF
Organic waste < 50 tons/day and total quantity > 200 tons/day	MRF + Composting + Incineration
Organic waste > 50 tons/day and total quantity > 50 tons/day	MRF + AD + RDF
Organic waste > 50 tons/day and total quantity > 200 tons/day	MRF + AD + Incineration

The characteristic of incoming waste is thus firstly analysed subject to the criteria in Table 4-9 and the characteristic suitability score of implemented MSW processing technologies is subsequently determined subject to the scoring criteria given in Table 4-10.

Table 4-10: Scoring criteria for the characteristic suitability

Conditions	Score
None of recommended processing technologies is implemented	0
Only one of recommended processing technologies is implemented	0.33
Only two of recommended processing technologies are implemented	0.67
All recommended processing technologies are implemented	1

The recovered proportion is subsequently calculated as:

$$\boldsymbol{Recovered\ proportion} = \frac{\boldsymbol{Total\ quantity\ of\ incoming\ waste}\ \left(\frac{\boldsymbol{tons}}{\boldsymbol{day}}\right)}{\boldsymbol{Total\ quantity\ of\ recoverable\ waste}\ (\frac{\boldsymbol{tons}}{\boldsymbol{day}})}$$

Based on the information of Pollution Control Department (PCD 2005; 2006; 2007), the amount of recoverable MSW accounted for about 90% of total generated waste. This figure is then used to determine the total quantity of recoverable waste.

The example is explained here. For the local authority **A**, material recovery facilities (MRF) and composting are available with the capacity of 10 tons/day and 5 tons/day respectively. Two tons of waste is going to MRF while 0.5 tons is going to composting each day. The total waste quantity is 16 tons/day and the waste composition is given in Table 4-11.

Table 4-11: Example of incoming waste composition

Components	% by weight
Food waste	58.2
Paper	6.1
Plastic	14.6
Glass	8.2
Metal	1.0
Others	11.9
Total	**100**

According to the given information, the capacity sufficiency score is equal to:

$$\boldsymbol{Capacity\ sufficiency} = \frac{\mathbf{2 + 0.5}\ (\frac{\boldsymbol{tons}}{\boldsymbol{day}})}{\mathbf{10 + 5}\ \left(\frac{\boldsymbol{tons}}{\boldsymbol{day}}\right)} = \mathbf{0.17}$$

The characteristic suitability is subsequently checked. From Table 4-9, the processing technologies that should be implemented are MRF, composting and RDF (organic waste = 9 tons/day and total waste = 16 tons/day). In fact, MRF and composting are implemented. Thus, the characteristic suitability subject to Table 4-10 is equal to:

$$\boldsymbol{Characteristic\ suitability} = \mathbf{0.67}$$

The recovered proportion is finally calculated as:

$$\boldsymbol{Recovered\ proportion} = \frac{\mathbf{2.5}\frac{\boldsymbol{tons}}{\boldsymbol{day}}}{\mathbf{90\%}\ \boldsymbol{x}\ \mathbf{16}\frac{\boldsymbol{tons}}{\boldsymbol{day}}} = \frac{\mathbf{2.5}}{\mathbf{14.4}} = \mathbf{0.18}$$

Thus, **E3** is equal to:

$$\boldsymbol{E3} = \mathbf{0.17}\ \boldsymbol{x}\ \mathbf{0.67}\ \boldsymbol{x}\ \mathbf{0.18} = \mathbf{0.02}$$

4.2.1.4. Lifespan of Available disposal area (E4)

Despite various recoverable measures, land disposal must be available in MSW management system. Its lifespan is the most important issue as seeking a new site is extremely difficult nowadays. It is recommended by PCD (2001) that land disposal site should be designed for waste generated in the next 20 years. This figure is then used for the proposed assessment tool. This period is also considered sufficient for the complete degradation of organic substances, allowing landfill reusing process to recover the space or expand its lifespan. Thus;

$$\boldsymbol{E4} = \frac{\boldsymbol{Lifespan\ of\ current\ disposal\ site}\ (\boldsymbol{yrs})}{\boldsymbol{Expected\ Lifespan}\ (\mathbf{20}\ \boldsymbol{yrs})}$$

where;

$$\boldsymbol{Lifespan\ of\ current\ landfill}\ (\boldsymbol{yrs}) = \frac{\boldsymbol{Total\ volume\ of\ disposal\ site}\ (\boldsymbol{m^3})}{\boldsymbol{Total\ waste\ volume\ received\ at\ site\ each\ year}\ (\frac{\boldsymbol{m^3}}{\boldsymbol{yr}})}$$

$$\boldsymbol{Total\ volume\ of\ disposal\ site}\ (\boldsymbol{m^3}) = \boldsymbol{Land\ area}\ (\boldsymbol{m^2})\ \boldsymbol{x}\ \boldsymbol{Depth}\ (\boldsymbol{m})$$

$$\textit{Total waste volume received at site each year}\left(\frac{m^3}{year}\right)$$

$$= \textit{Total waste volume}\left(\frac{m^3}{year}\right) + \textit{Daily cover volume}\left(\frac{m^3}{year}\right)$$

$$\textit{Total waste volume}\left(\frac{m^3}{year}\right)$$

$$= \frac{\textit{Total waste quantity received at site each year}\left(\frac{tons}{year}\right)}{\textit{Compacted waste density at site}\left(\frac{m^3}{ton}\right)}$$

For example, the area of 10 rai is available for local authority **A** to dispose of 7 tons of waste per day. The depth of landfill is 7 meters and daily cover volume accounts for 10% of waste volume with 500 kg/m^3 compacted density. The collection efficiency is equal to 60%. It is assumed that the waste generation rate is constant throughout the year. Then,

$$\textit{Total volume of disposal site}\ (m^3)$$

$$= 10\ rai\ x\ 1,600\frac{m^2}{rai}\ x\ 7\ m = 112,000\ m^3$$

$$\textit{Total waste quantity received at site each year}$$

$$= 7\frac{tons}{day} x\ 365\ days = 2,592\frac{tons}{year}$$

$$\textit{Total waste volume} = \frac{2,592\left(\frac{tons}{year}\right) x\ 1,000\frac{kg}{ton}}{500\left(\frac{kg}{m^3}\right)} = 5,184\frac{m^3}{year}$$

$$\boldsymbol{Total\ waste\ volume\ received\ at\ site\ each\ year}$$

$$= \mathbf{5,184} \left(\frac{\boldsymbol{m^3}}{\boldsymbol{year}}\right) + \mathbf{10\%}\ \boldsymbol{x}\ \mathbf{5,184} \left(\frac{\boldsymbol{m^3}}{\boldsymbol{year}}\right) = \mathbf{5,703} \left(\frac{\boldsymbol{m^3}}{\boldsymbol{year}}\right)$$

$$\boldsymbol{Lifespan\ of\ current\ landfill\ (yrs)} = \frac{\mathbf{112,000}\ \boldsymbol{m^3}}{\mathbf{5,703}\,\frac{\boldsymbol{m^3}}{\boldsymbol{year}}} = \mathbf{19.6}\ \boldsymbol{yrs}$$

Therefore, **E4** is equal to

$$\boldsymbol{E4} = \frac{\mathbf{19.6}}{\mathbf{20}} = \mathbf{0.98}$$

4.2.1.5. Availability of Sanitary Landfill (E5)

This aspect checks whether existing disposal site is constructed and operated in a sanitary manner. Guideline recommended by Pollution Control Department (PCD 2001) for local authorities to regulate the disposal site was adopted. It is important to note that not all recommended measures were selected. Only the basic measures for preventing impact from leachate and landfill gas which are the most concerned environmental issue from landfill listed in Table 4-12 are checked. Therefore, the checklist can be expanded if more stringent standard is needed such storm water management system or buffer zone.

$$\boldsymbol{E5} = \frac{\boldsymbol{Total\ implemented\ sanitary\ measures}}{\boldsymbol{Total\ recommended\ sanitary\ measures}}$$

Table 4-12: Recommended measures for proper landfill site operation

No.	Recommended measures	Impact prevention category
1	Bottom liner is constructed	Leachate
2	Leachate collection system is constructed	Leachate
3	Landfill gas collection system is constructed	Landfill gas
4	Daily cover is implemented	Leachate, Landfill gas
5	Groundwater monitoring well is constructed	Leachate

Source: PCD 2001

Thus if only bottom liner and leachate collection system are constructed at the disposal site, **E5** is equal to

$$\boldsymbol{E5 = \frac{2}{5} = 0.4}$$

4.2.1.6. Environmental Impact (E6)

Environmental impact from MSW management system commonly comes from main management activities including storage, collection, processing, and disposal processes as summarised in Table 4-13. Although life cycle assessment (LCA) method is available to calculate these environmental impacts, this was not utilised in the proposed assessment tool due to the difficulty in acquiring data of the intended user. Qualitative evaluation then replaces.

Table 4-13: Common environmental impacts from inefficient MSW management

Activities	Related environmental impacts
Storage	- Odour - Aesthetic damage - Disease vector distract such flies, rats
Collection	- Gases from biodegradation process (CO_2, CH_4, NH_3, H_2S) - Exhausting gases (CO_2, NO_x) - Disease vector distract such flies, rats
Processing (composting, anaerobic digestion, RDF, incinerator)	- Air emission (CO_2, NO_x, CH_4, NH_3, H_2S, Fly ash, Dioxin) - Wastewater from processing
Disposal	- Emission gases (CO_2, CH_4) - Leachate (runoff, groundwater)

Environmental evaluation was made based on the fact that adverse impacts come from: storage process when all generated waste is not stored in provided containers, collection process when all stored waste is not collected on the collection day, processing facilities when proper pollution treatment system is not constructed, and land disposal when sanitary landfill does not exist. Thus, the environmental impacts of four main activities are concerned as;

$$\boldsymbol{E6} = \frac{\textbf{\textit{Total sanitised management activities}}}{\textbf{\textit{Total checked management activities}}}$$

The environmental impact of MSW management system of local authority **A** is calculated in Table 4-14. The efficiency of storage, collection, processing process, and disposal are obtained from previous sections. Only wastewater is available for composting facility. Each activity is considered sanitary only when the calculated efficiency is equal to 1. Therefore, the environmental impact of this system (**E6**) is equal to:

Table 4-14: Example of environmental impact evaluation

Activities	Active services	Efficiency	Sanitized activities	Remark
Storage	1	E1 = 1.00	1	Efficiency > 100%
Collection	1	E2 = 0.60	0	Efficiency < 100%
Processing facilities	1		0	Pollution treatment system is available for both MRF and composting plant
Disposal	1	E5 = 0.40	0	Disposal site is not fully operated in a sanitary manner
Total	**4**		**1**	

Thus,

$$\boldsymbol{E6 = \frac{1}{4} = 0.25}$$

4.2.2. THE LOCAL AUTHORITIES' CAPABILITY COMPONENT (LAC)

This component considers both planning and implementation capability of local authority for MSW management. The following aspects were checked;

1. the effectiveness of planning system
2. the efficiency of planning system
3. the budget availability, and
4. the problem priority

4.2.2.1. Planning System Effectiveness (L1)

The MSW planning system of each local authority was evaluated. The score is given as:

$$L1 = Planning\ Effectiveness\ score$$

which is equal to the summation of each planning component score as:

$$Planning\ Effectiveness\ Score = PS + PSS + DSS + IMS + PMS + AS$$

Where	PS	= the score of planning staff
	PSS	= the score of planning support system
	DSS	= the score of decision support system
	IMS	= the score of information management system
	PMS	= the score of planning management system
	AS	= the score of administrative structure

The score of each planning component was set based on its significance to the overall performance of the MSW planning system, which was obtained from the data collected via questionnaire. The questionnaire collected data on those six planning components and the planning output. Proper MSW planning output should consist of strategy (SP), project/program plan (PP), and day-to-day operating plan (OP).

As mentioned in Chapter 3, the collected data was analysed to determine the common characteristics of five groups based on the planning output, including the MSW planning systems that;

Group 1: did not produce any MSW management plan,

Group 2: produced only operating or program plan,

Group 3: produced both operating and program plans, Group 4: produced operating plan, program plan, and strategy or long term plan, and

Group 5: produced operating plan, program plan and strategy or long term plan containing all necessary information.

The analysis result is presented in Table 4-15. The performance is divided into three levels: Poor (P), Fair (F), and Good (G). The different characteristics are clearly illustrated.

Table 4-15: Common characteristics of each group of planning output

Planning System	**Performance**					
	G1		**G2**	**G3**	**G4**	**G5**
Planning staff (PS)	P	F/G	F/G	F/G	F/G	F/G
Planning supporting facilities (PSS)	P/F/G	P	P/F	F/G	G	G
Decision support system (DSS)	P/F/G	P	F/P	F/G	F/G	F/G
Information management system (IMS)	P/F/G	P/F/G	P/F/G	P/F/G	F/G	F/G
Planning management system (PMS)	P/F/G	P/F/G	P/F/G	P/F/G	F/G	F/G
Administrative structure (AS)	P/F/G	P/F/G	P/F/G	P/F/G	F/G	G
Available MSW management plans	**0**		**OP/ PP**	**OP, PP**	**OP, PP, SP**	**OP, PP, SP**

The result shows that for the first group (G1), in which all three types of MSW management plans were not prepared, it was found that planning staff (PS) were not available (P) or when planning staff was available (F/G), the performance of both the planning support tool (PSS) and decision support system (DSS) were poor (P) even though the performance of the information management system (IMS), planning management system (PMS) and administrative structure (AS) are fair (F) or good (G).

Group 2 illustrates that a plan (operating or program plan) was developed when planning staff (PS) was available with the support of either the PSS or DSS no matter how the IMS, PMS or AS perform. However, a plan was also developed when both PSS and DSS were not available (P), but PS was in good performance (G). The performance of Group 3 shows that both operating and program plans had been prepared when planning staff was available with the support of both PSS and DSS regardless of the performances of IMS, PMS and AS.

Considering Group 4, a strategy had been further prepared when PS was available while the PSS had a good performance and DSS had fair or good performances. Moreover, IMS had fair or good performance. Data on the collection and disposal process as basic services, the characteristics of their MSW, and the detail of the possible management alternatives are available and properly stored. PMS and AS also produced a fair performance. From Group 5, it was found that at least five planning components gave a good performance particularly when only one planning staff was available (F), all other five supporting components had a good performance (G).

The significance of each planning component in actual practice was consequently revealed. The planning staff (PS), planning support (PSS), and decision support systems (DSS) are fundamental requirement for starting up an MSW planning system – to prepare operating plan and program plan. Of these, the planning staff is the most important component followed by the planning support tool. Proper information (IMS) and planning management systems (PMS), and administrative structures (AS) are further required if strategy or long term plan is to be prepared. Importantly, the three latter components will affect the overall performance of the planning system only when PS, PSS and DSS are well established from the start.

In relation to their significance, the score of each planning component at each performance level was determined and is presented in Table 4-16. These numbers were obtained by a trial and error process based on the following criteria. The planning staff has the highest score because it is the most important component, followed by PSS and DSS, and IMS, PMS, and AS. Moreover, the calculated score of any planning system must clearly indicate its planning output level.

Table 4-16: The proposed scoring criteria of each planning system component

Planning system component	**Performance Score**		
	G	**F**	**P**
Planning Staff (PS)	0.305	0.295	0
Planning Supporting System (PSS)	0.155	0.140	0
Decision Support System (DSS)	0.145	0.130	0
Information Management System (IMS)	0.140	0.100	0
Planning Management System (PMS)	0.130	0.080	0
Administrative Structure (AS)	0.125	0.060	0
Total	**1.00**	**0.815**	**0**

Since the performance of IMS, PMS, and AS will affect the effectiveness of MSW planning system only if PS, PSS and DSS are well set up in place. The planning system score is fundamentally equal to:

$$\boldsymbol{MSW\ Planning\ effectiveness\ score = PS + PSS + DSS}$$

and if the calculated score reaches the level indicating that PS, PSS, and DSS are well established, the score of IMS, PMS, and AS can be added. The score of that planning system is then changed to:

$$\boldsymbol{MSW\ Planning\ effectiveness\ score = PS + IMS + DSS + PMS + PSS + AS}$$

In accordance with the conditions in Table 4-15, all possible performance scenario of MSW planning system regarding PS, PSS, and DSS are presented in Table 4-18. Scenario 26, 27, and 28 indicate that PS, PSS, and DSS are well established. The basic score of each scenario based on the scoring criteria in Table 4-16 is also presented. The example of basic score calculation is explained here.

$$\begin{aligned}\boldsymbol{Basic\ \ Planning\ effectiveness\ score\ of\ Scenario}\ \mathbf{8} &= \boldsymbol{PS + PSS + DSS}\\ &= \boldsymbol{P + G + F}\\ &= \mathbf{0 + 0.155 + 0.130}\\ &= \mathbf{0.285}\end{aligned}$$

The basic planning effectiveness score and its corresponding planning output is plotted in Figure 4-1.

Table 4-17: Score of each performance scenarios of MSW planning system

Group	**No. of plan prepared**	**Scenario**	**Performance level**			**Basic Effectiveness Score**
			PS	**PSS**	**DSS**	
1	**0**	1	P	P	P	0.000
		2	P	P	F	0.130
		3	P	P	G	0.145
		4	P	F	P	0.140
		5	P	F	F	0.270
		6	P	F	G	0.285
		7	P	G	P	0.155
		8	P	G	F	0.285
		9	P	G	G	**0.300**
		10	F	P	P	0.295
2	**1**	11	G	P	P	0.305
		12	F	P	F	0.425
		13	F	P	G	0.440
		14	F	F	P	0.435
		15	F	G	P	0.450
		16	G	P	F	0.435
		17	G	P	G	0.450
		18	G	F	P	0.445
		19	G	G	P	**0.460**
3	**2**	20	F	F	F	0.565
		21	F	F	G	0.580
		22	G	F	F	0.575
		23	G	F	G	0.585
		24	F	G	F	0.580
		25	G	G	F	**0.590**
4	**3**	26	F	G	G	0.595
		27	G	G	G	**0.605**
5	**3**	28	G	G	G	**0.605**

The developed scoring criteria clearly indicate the planning output. As can be seen, the planning systems with the basic score less than or equal to 0.300 were unable to prepare any plan (G1), the score between 0.300 and 0.500 were able to prepare only one MSW management plan (G2), the score between 0.500 and 0.595 were able to prepare two types of MSW management plans (G3), and the score equal to or higher than 0.595 were able to prepare three types of MSW management plans (G4 and G5). It is important to note that the efficiency of these available MSW management plans is regardless.

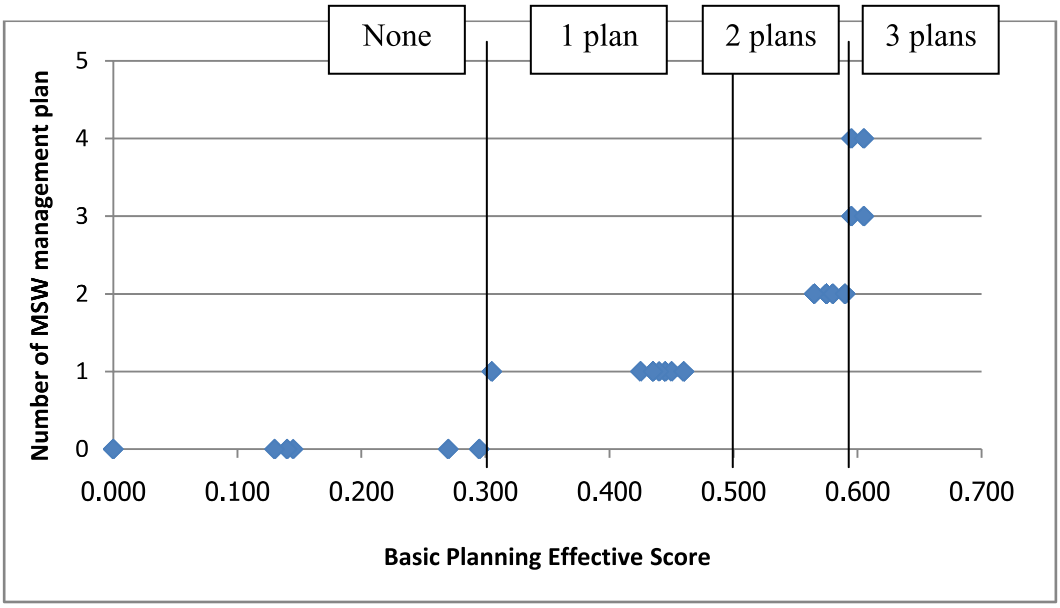


Figure 4-1 : The relationship between the basic planning effectiveness score and its corresponding planning output

Therefore, the score of IMS, PMS, and AS is added to the planning effectiveness score when the summation of PS, PSS and DSS is higher than 0.595 (Group 4 and 5) or:

$\boldsymbol{MSW\ Planning\ effectiveness\ score}$

$$= \boldsymbol{PS + PSS + DSS}, \quad when\ PS + PSS + DSS < 0.595$$

$$= \boldsymbol{PS + PSS + DSS + IMS + PMS + AS}, \quad when\ PS + PSS + DSS \geq 0.595$$

An example of the planning system score calculation is given in Table 4-18, where the score of each planning component is subjected to Table 4-16. The summation of PS, PSS, and DSS of Case I and Case II is lower and equal to than 0.595 respectively.

$$\boldsymbol{Basic\ Planning\ effectiveness\ score\ of\ Case\ I} = \boldsymbol{PS} + \boldsymbol{PSS} + \boldsymbol{DSS}$$

$$= \boldsymbol{F} + \boldsymbol{P} + \boldsymbol{P}$$

$$= \boldsymbol{0.295} + \boldsymbol{0} + \boldsymbol{0}$$

$$= \boldsymbol{0.295} < 0.595$$

Thus, $\boldsymbol{Planning\ effectiveness\ score\ of\ Case\ I} = \boldsymbol{PS} + \boldsymbol{PSS} + \boldsymbol{DSS} = \boldsymbol{0.295}$

$$\boldsymbol{Basic\ Planning\ effectiveness\ score\ of\ Case\ II} = \boldsymbol{PS} + \boldsymbol{PSS} + \boldsymbol{DSS}$$

$$= \boldsymbol{F} + \boldsymbol{G} + \boldsymbol{G}$$

$$= \boldsymbol{0.295} + \boldsymbol{0.155} + \boldsymbol{0.145}$$

$$= \boldsymbol{0.595} = \boldsymbol{0.595}$$

Thus, $\boldsymbol{Planning\ effectiveness\ score\ of\ Case\ II}$

$$= \boldsymbol{PS} + \boldsymbol{PSS} + \boldsymbol{DSS} + \boldsymbol{IMS} + \boldsymbol{PMS} + \boldsymbol{AS}$$

$$= (\boldsymbol{F} + \boldsymbol{G} + \boldsymbol{G}) + \boldsymbol{G} + \boldsymbol{G} + \boldsymbol{G} = \boldsymbol{0.595} + \boldsymbol{0.140} + \boldsymbol{0.130} + \boldsymbol{0.125} = \boldsymbol{0.985}$$

Table 4-18: Example of planning system score calculation

Planning Component	Case 1		Case 2	
	Performance Level	**Score**	**Performance Level**	**Score**
Planning Staff (PS)	F	0.295	F	0.295
Planning Supporting System (PSS)	P	0	G	0.155
Decision Support System (DSS)	P	0	G	0.145
Information Management System (IMS)	F	0.100	G	0.140
Planning Management System (PMS)	P	0	G	0.130
Administrative Structure (AS)	G	0.120	G	0.120
PS, PSS, DSS components score		**0.295**		**0.595**
All components score		**0.515**		**0.985**
Planning effectiveness score		**0.295**		**0.985**

The planning effectiveness score according to the scoring criteria in Table 4-16 and its corresponding planning output of studied local authorities is also plotted as shown in Figure 4-2. Similarly, the assigned scores to each planning system component can clearly identify the performance level of the MSW planning system or the types of planning output. Therefore, the developed mathematical model and scoring criteria of planning component can reasonably illustrate the MSW planning capability of local authorities in Thailand. The planning effectiveness score subjected to each level of planning output is summarised in Table 4-19.

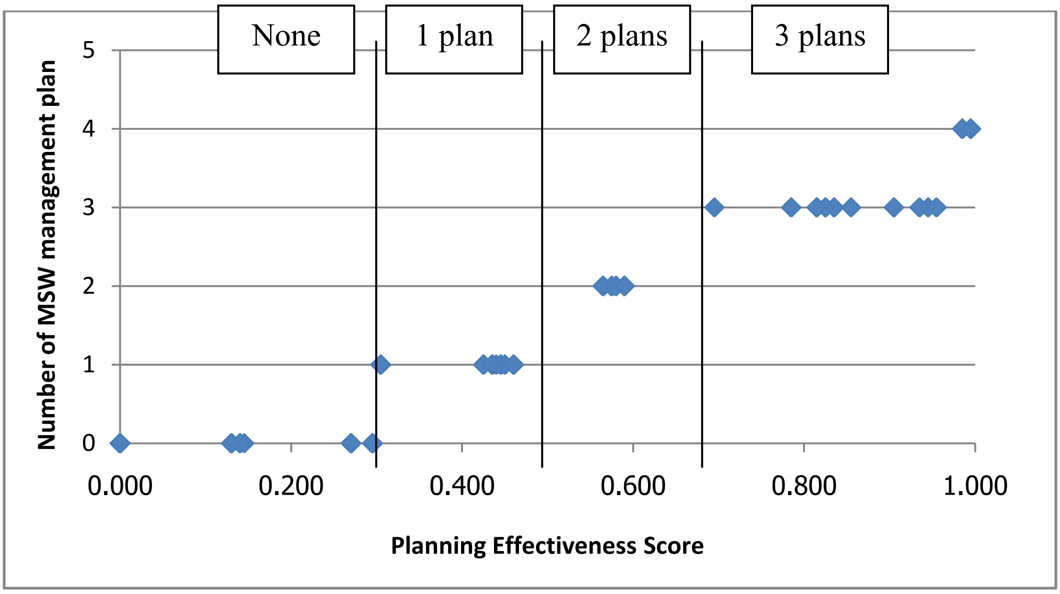


Figure 4-2: The relationship between the score of MSW planning system and its corresponding planning output

Table 4-19: Planning effectiveness score subjected to each level of planning output

Group	Planning Effectiveness Score	Planning Output Scenarios			No. of plan prepared
		Strategy	Program Plan	Operating Plan	
5	≥ 0.955	G	G	G	3
4	0.595 – 0.955	G/F	G/F	G/F	3
3	0.565 – 0.590	G/F	G/F	P	2
		G/F	P	G/F	
		P	G/F	G/F	
2	0.305 – 0.460	G/F	P	P	1
		P	G/F	P	
		P	P	G/F	
1	0 – 0.295	P	P	P	0

4.2.2.2. Planning System Efficiency (L2)

This aspect checks whether the planning output is produced according to the capacity of its planning system. A new method to evaluate the planning efficiency was also proposed. As illustrated in the last section, the planning output of any planning system can be predicted according to its planning effectiveness score as summarized in Table 4-20. For example, the planning effectiveness score system with the score between 0.565 and 0.590 should be able to prepare MSW operating and project plans.

Table 4-20: Performance of planning output subject to planning system score

Planning system score	No. of plan prepared
≥ 0.955	3*
0.595 – 0.955	3
0.565 – 0.590	2
0.305 – 0.460	1
0 – 0.300	0

The findings were consequently used to set up criteria for evaluating the efficiency MSW planning systems of local authorities in Thailand. Thus, the planning efficiency (L2) is thus calculated as:

$$\boldsymbol{L2} = \frac{\textbf{\textit{Number of MSW management plans actually prepared}}}{\textbf{\textit{Number of MSW management plans that should be prepared}}}$$

The criteria developed were verified by comparing the types of MSW management plans predicted by them with the actual MSW management plans produced or available. The results are shown in Figure 4-3. This illustrates that none of the

MSW planning systems developed under the condition applying in Group 1 can develop any type of MSW management plan.

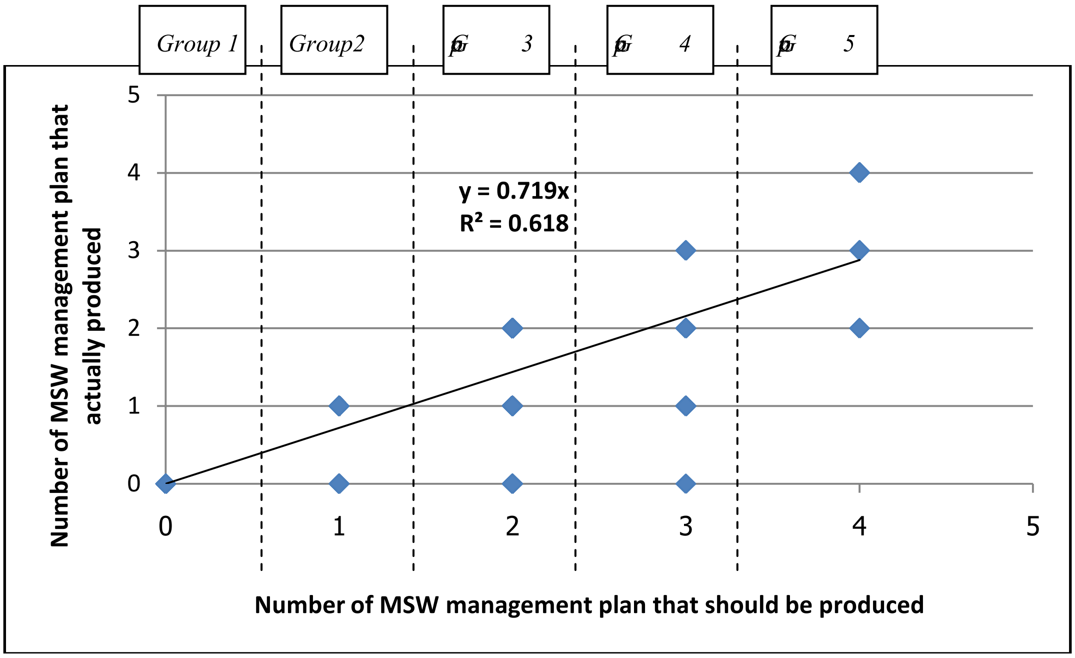


Figure 4-3: Comparison of predicted and actual planning output

Although some MSW planning systems within other groups produced fewer MSW management plans than predicted, the evaluation criteria set up were convincingly reliable because no MSW planning systems produced more MSW management plans than that had been predicted. Accordingly, the findings could indicate that their planning capability was not fully utilised – not efficient or that no attention was paid to the planning issues. Most of these bodies are Tambon Administrative Organisations, the lowest level of local authority in Thailand and operating in rural areas. It can also preliminary conclude that there are two main causes of the current weakness of MSW planning systems in Thailand: insufficient resources and/or ineffective management.

Thus, in case, the planning system effectiveness of local authority A (L1) is equal to 0.43 in which either operating plan or program plan should be produced but no MSW management plan has been prepared.

$$\boldsymbol{L2 = \frac{0}{1} = 0}$$

4.2.2.3. Budget Availability (L3)

Without sufficient budget, it is difficult to regulate the implemented MSW management system and sustain its performance. Once the appropriate system is designed, the implementation feasibility depends largely on available budget. Local authority basically requires budget for system construction and operation. Since the proposed assessment tool evaluates the existing MSW management system, only the sufficiency of operating cost is checked. The annual operating budget that local authorities have set out in the annual development plan is used. The common operating unit cost of MSW management system is used. Thus, **L3** is calculated as

$$\boldsymbol{L3 = \frac{Available\ annual\ operating\ budget}{Required\ operating\ cost}}$$

$$\boldsymbol{Required\ coperating\ cost = Unit\ operating\ cost\ \left(\frac{Baht}{ton}\right) x\ Waste\ quantity\ (\frac{tons}{day})}$$

Based on the experiences of various local authorities, the common operating unit cost (both collection and disposal cost) of municipalities varies greatly from 500 – 1,500 Baht/ton due to the socio-economic structure and the management efficiency (DEE 2010). However, the proposed assessment tool uses the minimum 500

Baht/ton for evaluation as an average operating cost for all forms of local authorities both in rural and urban areas. The criteria used are also checked by asking local authority whether insufficient budget is one of the barriers of their current MSW management.

In case of local authority A in which the budget of 500,000 Baht is set out each year for managing 16 tons of waste generated each day, **L3** is as follows:

$$\boldsymbol{L3 = \frac{500,000\ \frac{Baht}{year}}{500\ \frac{Baht}{ton}\ x\ 16\ \frac{tons}{day}\ x\ 365\ \frac{days}{year}} = 0.17}$$

4.2.2.4. Problem Priority (L4)

The priority to MSW management issue of any local authority was simply checked via the implementation of main activities intrinsically illustrating that local authority is giving attention to MSW problem. Based on the experiences of various countries, these activities commonly include:

1. Local authority has campaign to encourage source separation
2. Container is provided for source separated waste
3. Collection vehicle is provided for separated waste
4. Solid waste is one of environmental policy
5. Local authority looks for new method for MSW

Local staff was asked to check the existing of these activities. These activities can be expanded if needed. Thus, the management priority is calculated as:

$$L4 = \frac{Total\ implemented\ activities}{Total\ checked\ activities}$$

If collection vehicle is provided for separated waste and solid waste is one of environmental policy,

$$L4 = \frac{2}{5} = 0.4$$

4.2.3. THE PUBLIC PARTICIPATION COMPONENT (P)

This component evaluates the attitude of the public towards MSW management system. Two aspects were considered: public awareness and public willingness. Various MSW related process at present require the participation of the community to maximize the efficiency. Since no mathematical model is available for evaluating this component, common activities related to each evaluation aspect were consequently checked. Other activities can be added in the future if needed.

4.2.3.1. Public Awareness (P1)

Common activity illustrating the awareness of the public on the MSW management is to promote source separation campaign. The public participation in source separation campaign was checked by asking the local authority. Each local authority is also asked to judge whether the public was greatly aware of MSW issue. Thus:

$$P1 = Public\ awareness$$

The scoring criteria of P1 are given in Table 4-21.

Table 4-21: Scoring criteria for the public awareness evaluation

Public awareness activities	P1 Score
Public is not involved in source reduction campaign and local authority considers that the public is unaware of MSW issue	0
Public is involved in source reduction campaign or local authority considers that the public is well aware of MSW issue	0.5
Public is involved in source reduction campaign and local authority considers that the public is well aware of MSW issue	1

4.2.3.2. Public Willingness (P2)

Fundamental MSW related activities that the public actually involved themselves in were checked by asking the local authority to determine the public participation willingness. The activities that the public should involve themselves in are as follows:

1. collection,
2. source separation for recycling, and
3. source separation for central or home composting processes

In addition, local authority was asked whether unwilling public was one of the problems for managing MSW in their area at present in order to ensure the evaluation result. Four issues were checked. Therefore:

$$\boldsymbol{P2} = \frac{\textbf{\textit{Total activities that public involved themselves in}}}{\textbf{\textit{Total checked activities}}}$$

For example, in case the public is only participating in home composting process but the local authority considers that insufficient for effective MSW management system,

$$\boldsymbol{P2 = \frac{2}{4} = 0.5}$$

4.2.4. THE COLLABORATION (CB)

The collaboration among local authority, technologies, and the public is another important factor to the efficiency of MSW management. All key players must be working together. Mathematical model is also not available for evaluating this component. Fundamental activities indicating their collaboration were checked instead by asking local authority. Similarly, other activities can be added later if needed.

4.2.4.1. Collaboration Encouragement (C1)

Local authority was firstly asked whether the MSW management participation campaign has been promoted. Thus,

$$\boldsymbol{C1 = 0, if\ participation\ campaign\ is\ not\ being\ promoted}$$

$$\boldsymbol{= 1, if\ participation\ campaign\ is\ being\ promoted}$$

4.2.4.2. Planning Process Collaboration (C2)

The planning related activities that local authority and public should work together were checked by asking local authority. Public was expected to involve themselves in three planning processes including

1. the preparation of strategy,
2. brainstorming or meeting for finalizing the strategy, and
3. public hearing process

Thus,

$$\boldsymbol{C2} = \frac{\boldsymbol{Total\ planning\ activities\ that\ public\ involved\ themselves\ in}}{\boldsymbol{Total\ checked\ planning\ activities}}$$

If the public is participating in braining storming and hearing process,

$$\boldsymbol{C2} = \frac{\boldsymbol{2}}{\boldsymbol{3}} = \boldsymbol{0.67}$$

4.2.4.3. Implementation Process Collaboration (C3)

The operating activities that local authority should work with the public were checked by also asking local authority. Regarding the activities indicated in the Public Participation component, the public was expected to cooperate with the local authority in four operating activities including

1. source separation campaign,
2. collection,
3. separation for recycling, and
4. separation for central or home composting processes

Thus,

$$\boldsymbol{C3} = \frac{\boldsymbol{Total\ operating\ activities\ that\ public\ involved\ themselves\ in}}{\boldsymbol{Total\ checked\ operating\ activiites}}$$

If the public and local authority are both involved in home composting process,

$$\boldsymbol{C3 = \frac{1}{4} = 0.25}$$

4.2.4.4. Technical Collaboration of Local Authority (C4)

Lastly, local authority must be able to handle the implemented technologies to ensure the efficiency of MSW management system. Thus, the conditions indicating that local authority can work with the operating MSW management system were checked by asking local authority. These conditions are:

1. Local authority can design the MSW management system by themselves
2. Local authority can efficiently operate the selected MSW management system by themselves
3. Selected operating technologies are suitable to current local conditions such as MSW characteristics, local capacity, and public participation, and
4. Public is not seriously complaining about the existing MSW management system

Thus.

$$\boldsymbol{C4 = \frac{Total\ conditions\ of\ efficient\ MSW\ management\ system\ that\ exist}{Total\ checked\ conditions}}$$

If local staff considers that they are unable to design and operate the MSW management by themselves and public complaint is reported,

$$\boldsymbol{C4 = \frac{1}{4} = 0.25}$$

The evaluation methods of all evaluation aspects are summarised in Table 4-22, Table 4-23, and Table 4-24.

Table 4-22: Score calculations of the Engineering System component

Evaluation Components	Evaluation Aspects	Score Calculation
Engineering System (ES)	∉ Storage capacity (E1)	$= \frac{Total\ container\ volume\ (m^3)}{Total\ generated\ waste\ volume\ (m^3)}$
	∉ Collection efficiency (E2)	$= \frac{Total\ collection\ truck\ volume\ (\frac{m^3}{day})}{Total\ generated\ waste\ volume\ (\frac{m^3}{day})}$
	∉ Processing technologies efficiency (E3)	$= Capacity\ sufficiency\ x\ Characteristic\ suitability\ x\ Recovered\ proportion$
	∉ Lifespan of available disposal area (E4)	$= \frac{Lifespan\ of\ current\ landfill\ (yrs)}{Expected\ Lifespan\ (20\ yrs)}$
	∉ Availability of sanitary landfill (E5)	$= \frac{Total\ implemented\ sanitary\ measures}{Total\ recommended\ sanitary\ measures}$
	∉ Environmental impact (E6)	$= \frac{Total\ sanitised\ management\ activities}{Total\ checked\ management\ activities}$

Table 4-23: Score calculations of the Local Authorities' Capability component

Evaluation Components	Evaluation Aspects	Score Calculation
Local authorities' Capability (LAC)	∉ Planning system effectiveness (L1)	$= Planning\ effectiveness\ score$ $= PS + PSS + DSS + IMS + PMS + AS$
	∉ Planning system efficiency (L2)	$= \frac{Number\ of\ MSW\ management\ plans\ actually\ prepared}{Number\ of\ MSW\ management\ plans\ that\ should\ be\ prepared}$
	∉ Budget availability (L3)	$= \frac{Available\ annual\ operating\ budget}{Required\ operating\ cost}$
	∉ Problem priority (L4)	$= \frac{Total\ implemented\ activities}{Total\ checked\ activities}$

Table 4-24: Score calculations of the Public Participation and the Collaboration components

Evaluation Components	Evaluation Aspects	Score Calculation
Public Participation (PP)	∉ Public awareness (P1)	$= Public\ awareness$ $= 0, 0.5, 1$
	∉ Public willingness (P2)	$= \frac{Total\ activities\ that\ public\ involved\ themselves\ in}{Total\ checked\ activities}$
Collaboration (CB)	∉ Collaboration encouragement (C1)	$= 0, 1$
	∉ Planning process collaboration (C2)	$= \frac{Total\ planning\ activities\ that\ public\ involved\ themselves\ in}{Total\ checked\ planning\ activities}$
	∉ Implementation process collaboration (C3)	$= \frac{Total\ operating\ activities\ that\ public\ involved\ themselves\ in}{Total\ checked\ operating\ activiites}$
	∉ Technical collaboration of local authority (C4)	$= \frac{Total\ conditions\ of\ efficient\ MSW\ management\ system\ that\ exist}{Total\ checked\ conditions}$

Accordingly, all input required from the local authority for the developed assessment tool is summarised in Table 4-25, Table 4-26, Table 4-27 and Table 4-28.

Table 4-25: Input data of Engineering System component

Evaluation Aspects	Input Data
∉ Storage capacity (E1)	∉ Size and number of containers ∉ Generated waste quantity (tons/day) ∉ Waste density (kg/m^3) ∉ Collection frequency (times/week) ∉ Collection efficiency
∉ Collection efficiency (E2)	∉ Size and number of collection trucks ∉ Number of collection trip (trips/day)
∉ Processing technologies efficiency (E3)	∉ Available processing technologies ∉ Waste composition ∉ Quantity of incoming waste to each facility (ton/day) ∉ Capacity of each facility (ton/day)
∉ Lifespan of available disposal area (E4)	∉ Area and depth of current land disposal site (rai) ∉ Quantity of waste received at the disposal site ∉ Compacted waste density (kg/m^3)
∉ Availability of sanitary landfill (E5)	∉ Implemented sanitary measures of land disposal site
∉ Environmental impact (E6)	∉ Available pollution treatment technologies of each processing facility

Table 4-26: Input data of Local authority's capability component

Evaluation Aspects	Input Data
∉ Planning system effectiveness (L1)	∉ Number of planning staff ∉ Available supports for planning staff (training, document, budget) ∉ Available computer-based analysis tool ∉ Activities before making the decision ∉ Available data/ information ∉ Data storage type and manner ∉ Criteria used to evaluate the management system ∉ Available planning related documents and storage manner ∉ Flexibility of administrative structure
∉ Planning system efficiency (L2)	∉ Type and detail of available MSW management plans
∉ Budget availability (L3)	∉ Available annual operating budget (Baht/year)
∉ Problem priority (L4)	∉ Implemented activities intrinsically indicating attention to waste problem

Table 4-27: Input data of Public Participation component

Evaluation Aspects	Input Data
∉ Public awareness (P1)	∉ Implemented activities intrinsically indicating public awareness
∉ Public willingness (P2)	∉ List of activities that public involved themselves in

Table 4-28: Input data of Collaboration component

Evaluation Aspects	Input Data
∉ Collaboration encouragement (C1)	∉ Availability of participation promotion campaign
∉ Planning process collaboration (C2)	∉ Planning activities that public involved themselves in
∉ Implementation process collaboration (C3)	∉ Operating activities that local authority and public both involved in
∉ Technical collaboration of local authority (C4)	∉ Conditions of efficient MSW management system that exist

4.3. CALCULATION OF SUSTAINABILITY SCORE

From those 16 evaluation aspects, the sustainability score of MSW management system evaluated was equal to:

$$\boldsymbol{Sustainability\ Score = ES + LAC + PP + CB}$$

where ES = score of E1 + E2 + E3 + E4 + E5 + E6

LAC = score of L1 + L2 + L3 + L4

PP = score of P1 + P2

CB = score of C1 + C2 + C3 + C4

Based on the multiple criteria decision analysis (MCDA) technique, however, weights are given to each evaluation aspect and evaluation component based on their significance to the efficiency of MSW management system found in the literature review (Chapter 2 – Table 2-7) before calculating the sustainability score. Weights were firstly assigned to each evaluation aspect within each evaluation component as presented in Table 4-29. Summation of all evaluation aspects' weight of each evaluation component was equal to 1.

Table 4-29: Weight of each evaluation aspect

Evaluation Components	Evaluation Aspects	Aspect Weight
Engineering system	∉ Storage capacity (E1)	0.10
	∉ Collection efficiency (E2)	0.10
	∉ Processing technologies efficiency (E3)	0.10
	∉ Lifespan of available disposal area (E4)	0.30
	∉ Availability of sanitary landfill (E5)	0.30
	∉ Environmental impact (E6)	0.10
Local authority capability	∉ Planning system effectiveness (L1)	0.35
	∉ Planning system efficiency (L2)	0.15
	∉ Budget availability (L3)	0.15
	∉ Problem priority (L4)	0.35
Public participation	∉ Public awareness (P1)	0.50
	∉ Public willingness (P2)	0.50
Collaboration	∉ Collaboration encouragement (C1)	0.25
	∉ Planning process collaboration (C2)	0.25
	∉ Implementation process collaboration (C3)	0.25
	∉ Technical collaboration of local authority (C4)	0.25

Weights were assigned to each evaluation aspect according to its comparative significance within the evaluation component to the performance of MSW management system. More important aspect received higher weight based on the actual experiences of other countries reviewed in Chapter 2 and the author. As a result, the weights of the availability and sufficiency of sanitary landfill, the effectiveness of MSW planning system, and the problem priority were slightly higher than other aspects. These aspects were fundamentally required for moving towards effective MSW management system. The assigned weights were subsequently verified to check the reliability. The detail is presented in the next section.

Weights were subsequently assigned to each evaluation component. Similarly, the summation of all four components' weight was equal to 1. In actual practice, local staff can assign the weight of each evaluation component by themselves according to their local conditions. However, suitable weights based on the actual experiences of various local authorities in Thailand were determined. Thus, various weighting scenarios for evaluation components presented Table 4-30 subject to different conditions were studied.

Table 4-30: Weighting scenarios for each evaluation component

Scenarios	**Tested condition**	**Weighting Scenario**			
		ES	**LAC**	**PP**	**CB**
1	Equally important	0.25	0.25	0.25	0.25
2	ES and LAC are more important than PP and CB	0.30	0.30	0.20	0.20
3		0.35	0.35	0.15	0.15
4		0.40	0.40	0.10	0.10
5		0.50	0.50	0.0	0.0
6	ES and LAC are less important than PP and CB	0.20	0.20	0.30	0.30
7		0.15	0.15	0.35	0.35
8		0.05	0.05	0.45	0.45
9		0.0	0.0	0.50	0.50
10	ES is the most important component	0.45	0.25	0.20	0.10
11		0.50	0.30	0.20	0.0
12		0.60	0.25	0.10	0.05
13	LAC is the most important component	0.30	0.50	0.20	0.0
14		0.25	0.45	0.20	0.10
15		0.25	0.60	0.10	0.05
16	PP is the most important component	0.0	0.30	0.50	0.20
17		0.10	0.25	0.45	0.20
18		0.05	0.25	0.60	0.10
19	CB is the most important component	0.0	0.20	0.30	0.50
20		0.10	0.20	0.25	0.45
21		0.05	0.10	0.25	0.60

The best scenario was then determined. In doing so, the sustainability score of local authorities under each weighting scenario was calculated. The results were then plotted against the actual performance level of MSW management system which is classified into six levels as described in Table 4-31. The analysis rationale was that the higher sustainability score, the higher performance level of MSW management system. The best weighting scenario gives the best correlation (R^2).

Table 4-31: Performance level of MSW management system

Performance Level	**Description**
0	No system is in place
1	System is in place, but not sufficient
2	System is in place, sufficient, but not regular
3	System is in place, sufficient, regular, but not environmentally friendly
4	System is in place, sufficient, regular, environmentally friendly, but not sustainable
5	System is in place, sufficient, regular, environmentally friendly, and sustainable

Accordingly, the second questionnaire was given to 71 local authorities from southern provinces of Thailand who attended solid waste lecture given by the author. All four forms of local authority were included. The number of each form is summarized in Table 4-32. Although 60 local authorities returned the questionnaires, only 46 of them (66%) could be used for analysis (complete answers). However, data of four municipalities from other regions of Thailand were obtained from other sources. Thus, the data of 50 local authorities were used.

Table 4-32: Number of southern local authorities returned the second questionnaire

Form of Local authority	Number of Local authorities		
	Targeted	Returned	Return Rate
Nakhon municipality (NM)	2	2	100%
Muang municipality (MM)	5	5	100%
Tambon municipality (TM)	15	10	67%
Tambon administrative organization (TAO)	49	43	88%
Total	**71**	**60**	**85%**

Each local authority was asked in the second questionnaire to provide data and information listed in Table 4-25, Table 4-26, Table 4-27, and Table 4-28. Local authorities were also asked to rate the performance level of their current MSW management system in the questionnaire. The collected data of these 51 local authorities were analysed. The sustainability score was subsequently calculated.

The example of how the sustainability score is calculated for the local authority A under the weighting scenario 1 (Table 4-30) is illustrated in Table 4-33. The calculated scores of each evaluation aspect are given in Column 2. Weights of evaluation aspects (Table 4-29) and evaluation components (Table 4-30) are presented in Column 3 and 4 respectively. Score of each evaluation component is subsequently calculated and presented in Column 5 as shown below:

$$\boldsymbol{Component\ score\ = Component\ weight\ x \sum Aspect\ weight\ x\ Calculated\ score}$$

Thus,

$$\boldsymbol{Engineering\ system\ component\ score}$$

$$= \mathbf{0.25}\ \boldsymbol{x}\ (\mathbf{0.1}\boldsymbol{x}\mathbf{1.0} + \mathbf{0.1}\boldsymbol{x}\mathbf{0.85} + \mathbf{0.1}\boldsymbol{x}\mathbf{0.1} + \mathbf{0.3}\boldsymbol{x}\mathbf{0.465} + \mathbf{0.3}\boldsymbol{x}\mathbf{0.4} + \mathbf{0.1}\boldsymbol{x}\mathbf{0.25})$$

$$= \mathbf{0.12}$$

Table 4-33: MSW management system score calculation

Evaluation Components	Evaluation Aspects (1)	Evaluated score (2)	Aspect Weight (3)	Component Weight (4)	Component score (5)
Engineering System (ES)	E1	1.000	0.10	0.25	0.12
	E2	0.850	0.10		
	E3	0.100	0.10		
	E4	0.465	0.30		
	E5	0.400	0.30		
	E6	0.250	0.10		
Local authorities' Capability (LAC)	L1	0.430	0.35	0.25	0.08
	L2	0.000	0.15		
	L3	0.130	0.15		
	L4	0.400	0.35		
Public Participation (PP)	P1	0.500	0.50	0.25	0.125
	P2	0.500	0.50		
Collaboration (CB)	C1	0.000	0.25	0.25	0.08
	C2	0.670	0.25		
	C3	0.250	0.25		
	C4	0.250	0.25		
				Sustainability Score	**0.41**

$$\boldsymbol{Local\ authority's\ capability\ component\ score}$$

$$= \mathbf{0.25\ x\ (0.35x0.43 + 0.15x0 + 0.15x0.13 + 0.35x0.4) = 0.08}$$

$$\boldsymbol{Public\ participation\ component\ score}$$

$$= \mathbf{0.25\ x\ (0.5x0.5 + 0.5x0.5) = 0.125}$$

$$\boldsymbol{Collaboration\ component\ score}$$
$$= \mathbf{0.25}\ \boldsymbol{x}\ (\mathbf{0.25}\boldsymbol{x}\mathbf{0} + \mathbf{0.25}\boldsymbol{x}\mathbf{0.67} + \mathbf{0.25}\boldsymbol{x}\mathbf{0.25} + \mathbf{0.25}\boldsymbol{x}\mathbf{0.25}) = \mathbf{0.08}$$

Therefore;

$$\boldsymbol{Sustainability\ score} = \mathbf{0.12} + \mathbf{0.08} + \mathbf{0.125} + \mathbf{0.08} = \mathbf{0.41}$$

The calculated sustainability scores of those 51 local authorities under the weighting scenario 1 were subsequently plotted against the given performance levels as shown in Figure 4-5. The correlation or R^2 is equal to 0.889 and the sustainability score of each performance level is not clearly divided. Overlapping of sustainability score between each performance level is observed. Therefore, the weighting scenario 1 is not well represented the sustainability of analysed MSW management system.

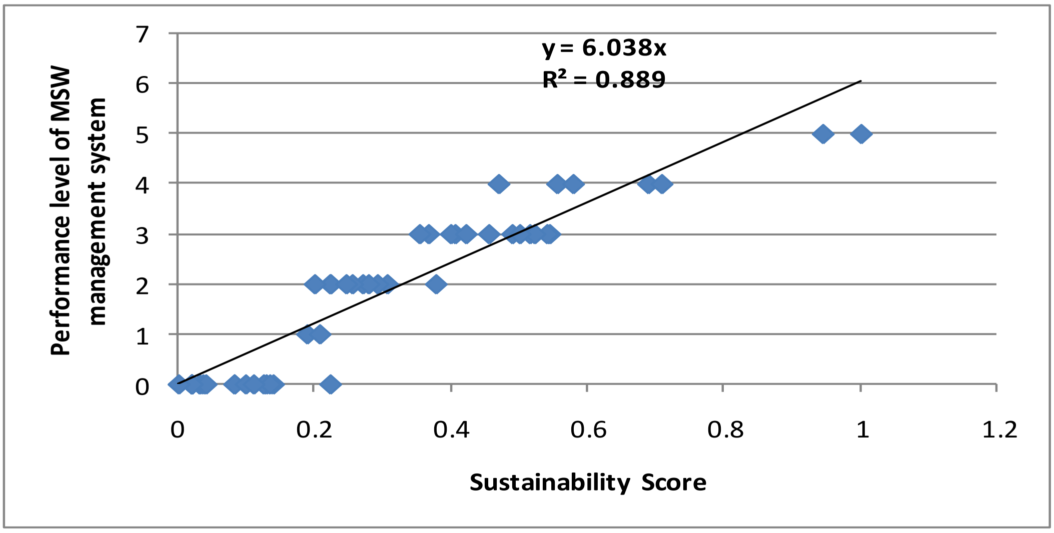


Figure 4-4: The correlation of the calculated sustainability scores and the given performance levels under the evaluation component weighting scenario 1

Other weighting scenarios in Table 4-30 were then tested. The best scenario should provide the highest R^2 and clearly distinguish the score of each performance level. The result is illustrated in Table 4-34.

Table 4-34: R^2 of each evaluation component weighting scenario

Scenarios	Condition	Component weight				R^2	Over-Lap
		ES	LAC	PP	CB		
1	Equally important	0.25	0.25	0.25	0.25	0.889	/
2	ES and LAC are more important than PP and CB	0.30	0.30	0.20	0.20	0.921	/
3		**0.35**	**0.35**	**0.15**	**0.15**	**0.945**	**X**
4		**0.40**	**0.40**	**0.10**	**0.10**	**0.960**	**X**
5		0.50	0.50	0.0	0.0	0.966	/
6	ES and LAC are less important than PP and CB	0.20	0.20	0.30	0.30	0.847	/
7		0.15	0.15	0.35	0.35	0.796	/
8		0.05	0.05	0.45	0.45	0.669	/
9		0.0	0.0	0.50	0.50	0.595	/
10	ES is the most important component	0.45	0.25	0.20	0.10	0.953	/
11		**0.50**	**0.30**	**0.20**	**0.0**	**0.963**	**X**
12		0.60	0.25	0.10	0.05	0.970	/
13	LAC is the most important component	0.30	0.50	0.20	0.0	0.941	/
14		0.25	0.45	0.20	0.10	0.927	/
15		0.25	0.60	0.10	0.05	0.939	/
16	PP is the most important component	0.0	0.30	0.50	0.20	0.717	/
17		0.10	0.25	0.45	0.20	0.782	/
18		0.05	0.25	0.60	0.10	0.705	/
19	CB is the most important component	0.0	0.20	0.30	0.50	0.709	/
20		0.10	0.20	0.25	0.45	0.786	/
21		0.05	0.10	0.25	0.60	0.702	/

As can be seen, R^2 under the conditions that Engineering system (ES) and Local authorities' capability (LAC) are more important than Public participation (PP) and Collaboration (CB) (Scenario 3,4) and ES is the most important component (Scenario 11) gives the highest R^2 and clearly distinguish the score of each performance level as presented in Figure 4-5.

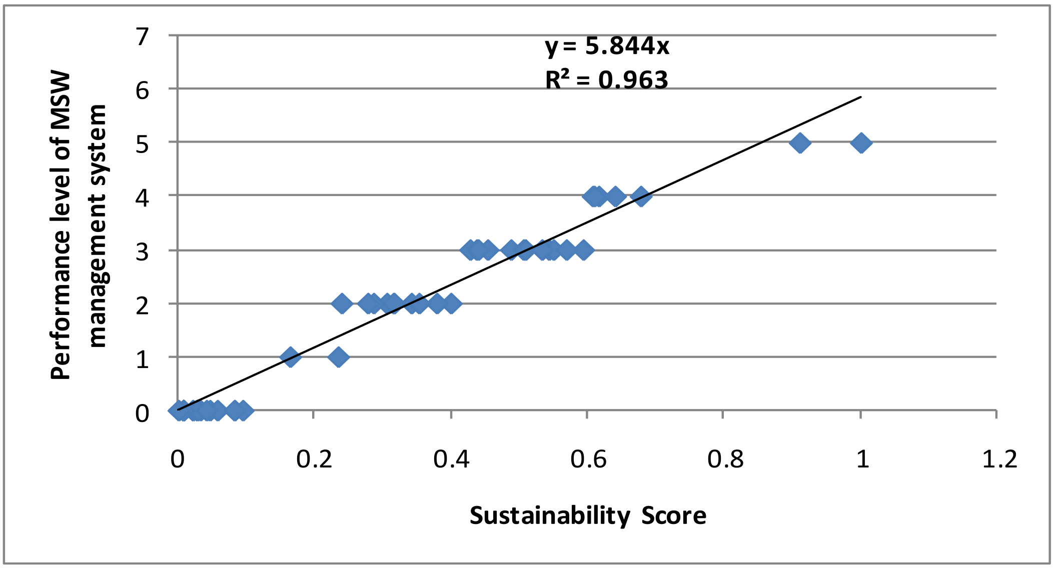


Figure 4-5: The correlation of the calculated sustainability score and the given performance level under the best evaluation component weighting scenario

Other scenarios under the condition that Engineering system (ES) and Local authorities' capability (LAC) are more important than Public participation (PP) and Collaboration (CB) with ES is the most important component were further developed and tested as presented in Table 4-35 to recheck the correlations.

Table 4-35: Possible weighting scenarios under the conditions that Engineering system (ES) is the most important component

Scenarios	Component weight			
	ES	LAC	PP	CB
22	0.50	0.40	0.05	0.05
23	0.50	0.30	0.10	0.10
24	0.50	0.30	0.15	0.05
25	0.50	0.30	0.05	0.15
26	0.50	0.25	0.15	0.10
27	0.50	0.25	0.10	0.15
28	0.50	0.25	0.20	0.05
29	0.50	0.25	0.05	0.20
30	0.50	0.20	0.15	0.15

The correlations of other weighting scenarios were determined and summarised in Table 4-36. Beside the correlation, the calculated sustainability score of each performance level should be clearly distinguished. Weighting scenario 22 gives the highest R^2.

Table 4-36: The correlations of each evaluation component weighting scenario

Scenarios	Weight				R^2
	ES	LAC	PP	CB	
22	0.50	0.40	0.05	0.05	0.969
23	0.50	0.30	0.10	0.10	0.966
24	0.50	0.30	0.15	0.05	0.966
25	0.50	0.30	0.05	0.15	0.964
26	0.50	0.25	0.15	0.10	0.962
27	0.50	0.25	0.10	0.15	0.961
28	0.50	0.25	0.20	0.05	0.960
29	0.50	0.25	0.05	0.20	0.958
30	0.50	0.20	0.15	0.15	0.956

The results from Table 4-34 and Table 4-36 illustrates that the sustainability scores calculated from the developed evaluation methods and the weighting scenario under the condition that ES is the most important component well correlated with the actual performance level indicated (R^2>0.9). The evaluation component weighting scenario 23 is considered as the best weighting scenario although weighting scenario 22 gives the highest R^2 because it clearly divides the performance level of MSW management system as presented in Figure 4-6. The sustainability scores subject to each performance level are summarised in Table 4-37. The higher performance level has a higher sustainability score. However, none of studied local authorities has gained the full sustainability score or 1.

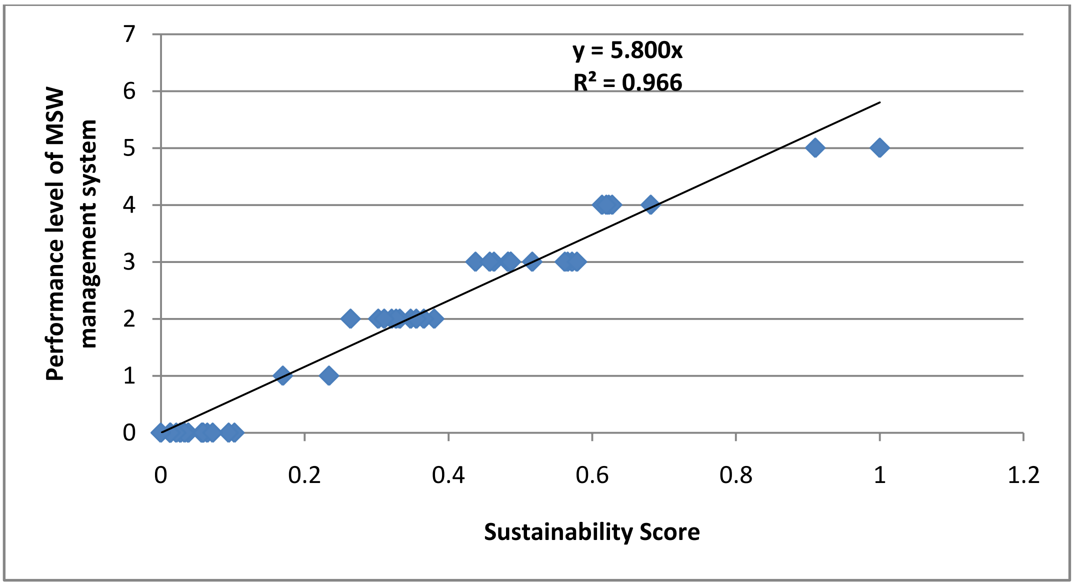


Figure 4-6: The correlation of the calculated sustainability score and the given performance level under the evaluation component weighting scenario 23

These findings indicate that the developed evaluation methods (both evaluation aspects and calculation methods) and the selected weighting scenario of the proposed assessment tool reasonably illustrated the sustainability score or level of exiting MSW management system in Thailand or well represented the actual practices. Moreover, the effectiveness of any MSW management system can also be predicted from the calculated sustainability score.

Table 4-37: Sustainability score at each system performance level

Performance Level	Description	Score
0	No system is in place	< 0.15
1	System is in place, but not sufficient	0.15 – 0.25
2	System is in place, sufficient, but not regular	0.25 – 0.40
3	System is in place, sufficient, regular, but not environmentally friendly	0.40 – 0.60
4	System is in place, sufficient, regular, environmentally friendly, but not sustainable	0.60 – 0.80
5	System is in place, sufficient, regular, environmentally friendly, and sustainable	> 0.80

The result also supports the experiences of other countries reviewed that the most important factor to the efficiency of MSW management system is the engineering system (ES), followed by the capability of local authority (LAC), public participation (PP), and the collaboration (CB). The result also shows that the Public participation and Collaboration components are equally important to the efficiency of MSW management system. Moreover, the analysed data illustrates that the sustainability score of Nakhon municipality, the highest level, is higher than Tambon Administrative Organisation, the lowest level.

4.4. CASE STUDIES

The sustainability score of few local authorities in Thailand are presented in details in this section to illustrate and discuss the applicability of the developed assessment tool to the actual situation.

4.4.1. Phitsanulok Nakhon Municipality

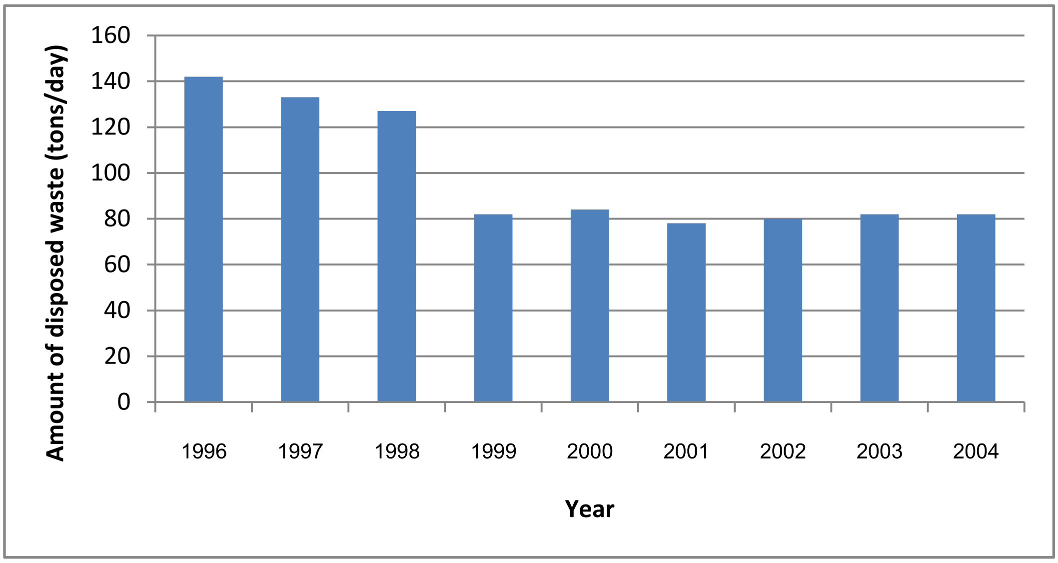
MSW management system of Phitsanulok Nakhon municipality is well known as one of the best practices in Thailand. With data filled in the questionnaire, the sustainability score of Phitsanulok Nakhon municipality is presented in Table 4-38.

Table 4-38: Sustainability score of Phitsanulok Nakhon municipality

Evaluation Components	Evaluation Aspects (1)	Evaluated score (2)	Aspect Weight (3)	Component Weight (4)	Component score (5)
Engineering System (ES)	E1	1.00	0.10	0.50	0.445
	E2	1.00	0.10		
	E3	0.72	0.10		
	E4	1.00	0.30		
	E5	0.80	0.30		
	E6	0.78	0.10		
Local authorities' Capability (LAC)	L1	1.00	0.35	0.30	0.27
	L2	1.00	0.15		
	L3	0.33	0.15		
	L4	1.00	0.35		
Public Participation (PP)	P1	1.00	0.50	0.10	0.10
	P2	1.00	0.50		
Collaboration (CB)	C1	1.00	0.25	0.10	0.10
	C2	1.00	0.25		
	C3	1.00	0.25		
	C4	1.00	0.25		
				Sustainability Score	**0.92**

Not surprisingly, its MSW management system has gained the highest sustainability score among the studied local authorities and is the only one falling in the 5th performance level or considered as sustainable MSW management system (Table 4-37). The calculated score indicates that all services (storage (E1), collection (E2), and disposal (E4)) are sufficiently provided. The public participation and collaboration is satisfied (P1, P2, C1, C2, C3, C4). Their planning capability is at full mark since all three types of MSW management plans have been produced. The analysis result is then checked with information available from other sources.

The service area of Phitsanulok Nakhon municipality is about 18.26 square kilometer with 90,000 people. The generated waste consisted of 40% compostable, 40% saleable and the remaining 20% for final disposal. At present, the public has been educated to enhance their awareness on the waste problem. Their participation in separating waste at home into three categories including organic waste for home composting, saleable materials for recycling, and the remaining for final disposal is thus high. Another key for this high participation rate is because the biggest recycling business of the country is located here. As a result, the amount of waste going to landfill was about 82 tons/day in 2004, significantly decreased from 140 tons/day in 1996 as shown in Figure 4-7.

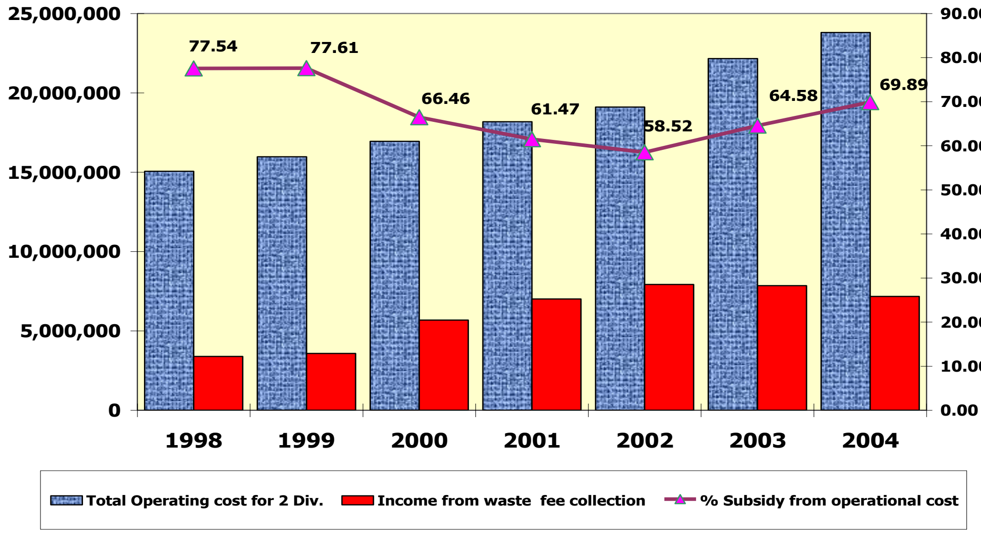


Source: Phitsanulok Nakhon municipality 2010

Figure 4-7: MSW quantity going to landfill of Phitsanulok Nakhon municipality

The remaining waste is transported to 220 rai landfill. At the site, the waste is treated with MBT or mechanical-biological waste treatment technology. Waste is unloaded and bulky waste is removed. The residual is lifted up the sides of a rotating drum where the plastic bags are spitted and waste is mixed and homogenized. The processed waste is subsequently composted. After 9 months, uncompostable material mainly plastics about 40%, planned to transformed into RDF, is currently disposed of in the landfill. With MBT technology, the lifespan of landfill site can be extended from 15-20 years to 50 years. Since all organics are removed, landfill gas is not produced and gas collection system is not installed. This is the reason why their E5 and E6 score are not at full mark. The developed assessment tool should then be adjusted in the future to handle this type of practice.

Considering their high planning capability (L1, L2), the academic support from GTZ may contribute to their success. However, since the effective MSW planning system has been established in their authority, the performance should be sustained when the support is finished. Unfortunately, the available operating budget as implementation indicator is only about 33% (L3 = 1.67/5) of the operating cost. The available information on the waste fee collection is in line with the analysis result as shown in Figure 4-8, where the collected waste fee is only 30% of the operating cost. One of the local staff was also interviewed and only the insufficient budget was indicated as their current problem. All these evidences have strengthened the reliability of the developed assessment tool although some features should be adjusted.



Source: Phitsanulok Nakhon municipality 2010

Figure 4-8: The financial performance of Phitsanulok Nakhon Municipality

4.4.2. Songkhla Nakhon Municipality

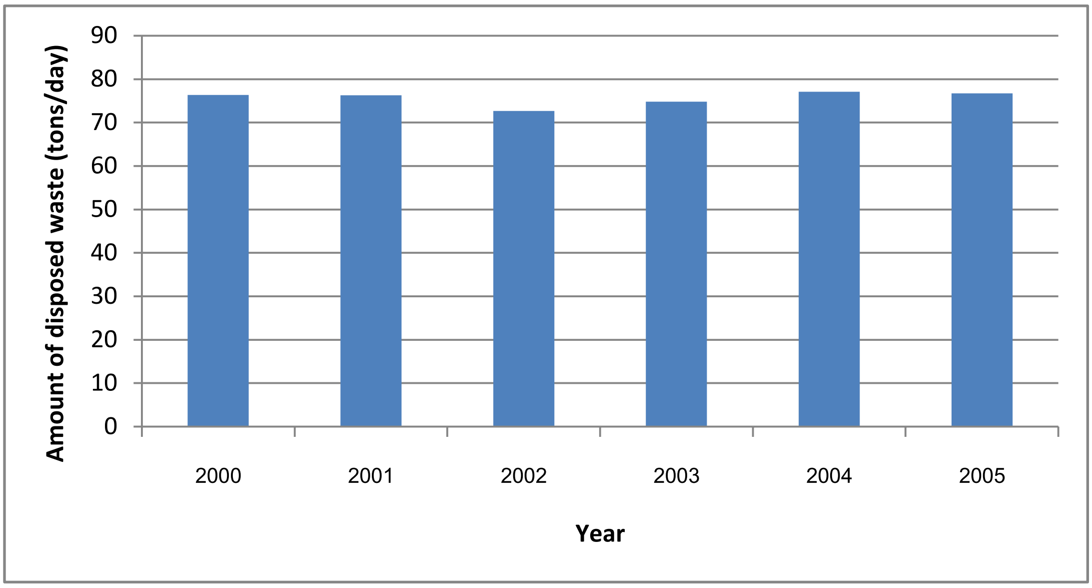
Their MSW management system is also acknowledged as one of the best practices. Its sustainability score is presented in Table 4-39. Their score is at the 4th performance level (Table 4-37). The service area of Songkhla Nakhon municipality is about 9.27 square kilometer with 80,000 people, two times highly populated than Phitsanulok Nakhon municipality. The generated waste is about 76 tons/day, consisting of 65% compostable, 20% saleable and others.

Absence of proper academic support and recycling business in the area could be a main reason for the lower score than Phitsanulok Nakhon municipality. However, the basic services (storage (E1) and collection (E2)) are sufficiently provided, which should be common for the top level of local authority. To support the calculated score, proper source reduction activities have been practiced but they are not sustained in the area. The public participation and collaboration is not as high as Phitsanulok Nakhon municipality.

Table 4-39: Sustainability score of Songkhla Nakhon municipality

Evaluation Components	Evaluation Aspects (1)	Evaluated score (2)	Aspect Weight (3)	Component Weight (4)	Component score (5)
Engineering System (ES)	E1	1.00	0.10	0.50	0.29
	E2	1.00	0.10		
	E3	0.00	0.10		
	E4	0.43	0.30		
	E5	0.60	0.30		
	E6	0.67	0.10		
Local authorities' Capability (LAC)	L1	0.58	0.35	0.30	0.18
	L2	0.50	0.15		
	L3	0.34	0.15		
	L4	0.80	0.35		
Public Participation (PP)	P1	1.00	0.50	0.10	0.09
	P2	0.75	0.50		
Collaboration (CB)	C1	1.00	0.25	0.10	0.07
	C2	0.34	0.25		
	C3	0.50	0.25		
	C4	1.00	0.25		
				Sustainability Score	**0.63**

Although the waste from Songkhla Nakhon municipality itself has leveled off in recent years as shown in Figure 4-9, the amount of waste going to landfill is increasing each year. This is caused by waste from other nearby local authorities. The landfill volume is quickly consumed. It is also found that no central processing facilities to reduce waste volume on a regular basis have been practiced. All incoming waste is landfilled.



Source: Songkhla Nakhon municipality 2010

Figure 4-9: MSW quantity going to landfill of Songkhla Nakhon municipality

The calculation illustrated that the site may last only for the next 10 years. According to the available information, the landfill site has been used for about 10 years and normally should be available for another 10 years (considering 20 years as a common lifespan). Proper landfill gas collection is also not installed.

Moreover, the comprehensive MSW management planning system is not available in the organisation. The long term of MSW management scheme is not yet prepared. Insufficient budget is also their problem. Based on the result of the developed assessment tool, their current MSW management system is yet considered as a sustainable management system. Although MSW would not seem to be a problem for the municipality in the next few years, proper waste reduction program or technology is required in order to avoid the problem and to achieve a sustainable level.

4.4.3. Hatyai Nakhon Municipality

The sustainability score of Hatyai Nakhon municipality's MSW management system is presented in Table 4-40. Their calculated score is even less than Songkhla Nakhon municipality or at 3rd performance level (Table 4-37). The measures to address their MSW problem are thus more urgent. The service area of Hatyai Nakhon municipality is about 21 square kilometer with 200,000 people. About 100 tons of MSW is produced each day. The generated waste consisted of 50% compostable, 30% saleable and the others.

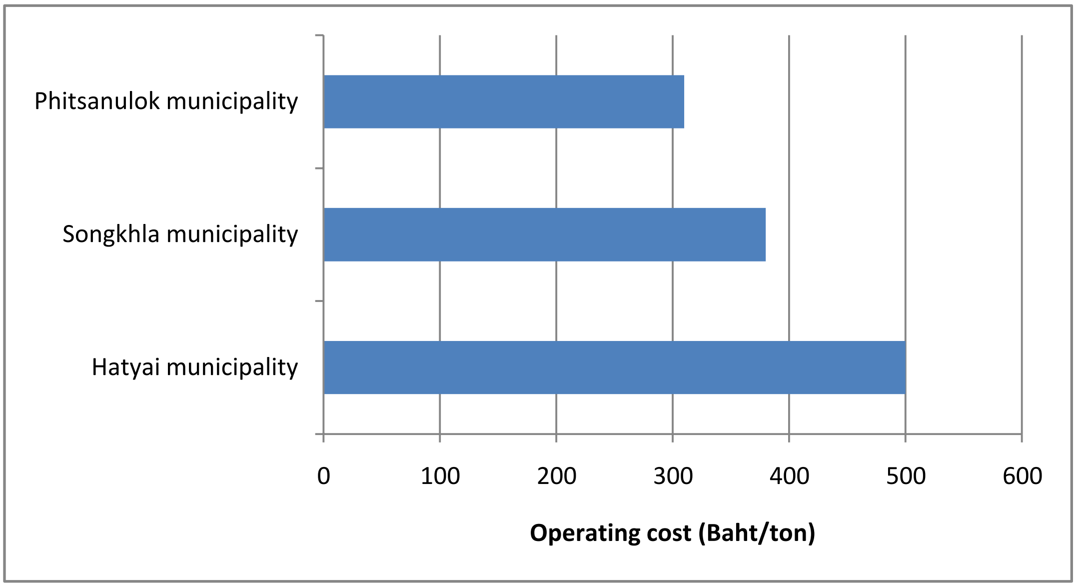
Table 4-40: Sustainability score of Hatyai Nakhon municipality

Evaluation Components	Evaluation Aspects (1)	Evaluated score (2)	Aspect Weight (3)	Component Weight (4)	Component score (5)
Engineering System (ES)	E1	1.00	0.10	0.50	0.18
	E2	1.00	0.10		
	E3	0.00	0.10		
	E4	0.00	0.30		
	E5	0.40	0.30		
	E6	0.44	0.10		
Local authorities' Capability (LAC)	L1	0.58	0.35	0.30	0.15
	L2	0.00	0.15		
	L3	0.20	0.15		
	L4	0.80	0.35		
Public Participation (PP)	P1	0.50	0.50	0.10	0.05
	P2	0.50	0.50		
Collaboration (CB)	C1	1.00	0.25	0.10	0.06
	C2	0.67	0.25		
	C3	0.00	0.25		
	C4	0.75	0.25		
				Sustainability Score	**0.44**

Without proper source reduction program, the amount of waste going to disposal site is increasing; part of the incoming waste is from nearby local authorities. Although, the central composting and recovery facilities have been practiced at the site with the support of JICA, the performance is not as good as before the support was finished. Only two tons of organic waste is processed at the facility. Almost all of incoming waste is directly landfilled (E3). The calculated score also indicates that their final disposal site is facing a serious problem (E4). The calculation shows that the lifespan of the disposal site lasts only about a year and it is also not sanitary landfill (E5).

Accordingly, a new Waste to Energy facility is being proposed to be constructed at the site due to the shortage of existing disposal area and public opposition to the new landfill site. The result of the developed assessment tool well supports the actual situation. The effectiveness of their planning capability (L1 and L2) is currently low as compared with the planning capabilities of Phitsanulok and Songkhla Nakhon municipalities. This could contribute to the inefficiency of processing facilities since the planning capability of local authority is crucial for sustaining the management performance.

Interestingly, the difference in the calculated sustainability score of these three local authorities is corresponded with their operating cost (Figure 4-10). The higher sustainability score, the lower operating cost implying higher efficiency. This is another evidence to support the result of the developed assessment tool.



Source: DEE 2006

Figure 4-10: MSW management operating cost of three Nakhon municipalities

4.4.4. Thakham Muang Municipality

Its sustainability score is presented in Table 4-41, which is falling in the 2nd performance level (Table 4-37). Attention to their MSW problem is clearly required. Thakham Muang municipality services 14 square kilometer with about 20,000 people. About 18 tons of MSW is produced daily. Organics accounts for 60% while saleable is about 30%.

Table 4-41: Sustainability score of Thakham Muang municipality

Evaluation Components	**Evaluation Aspects (1)**	**Evaluated score (2)**	**Aspect Weight (3)**	**Component Weight (4)**	**Component score (5)**
Engineering System (ES)	E1	1.00	0.10	0.50	0.12
	E2	0.99	0.10		
	E3	0.00	0.10		
	E4	0.05	0.30		
	E5	0.00	0.30		
	E6	0.22	0.10		
Local authorities' Capability (LAC)	L1	0.43	0.35	0.30	0.07
	L2	0.00	0.15		
	L3	0.03	0.15		
	L4	0.20	0.35		
Public Participation (PP)	P1	0.00	0.50	0.10	0.01
	P2	0.25	0.50		
Collaboration (CB)	C1	0.00	0.25	0.10	0.01
	C2	0.00	0.25		
	C3	0.25	0.25		
	C4	0.25	0.25		
				Sustainability Score	**0.21**

The score indicates that all generated waste is not collected (E2). Either insufficient collection vehicles or collection frequency could be the reason. However, only small room is needed. Comparing with the actual practice, all stored waste are collected but the collection vehicles without compaction mechanism are compacted manually by the collection crew to increase the MSW quantity collected. The developed assessment tool may need to be adjusted according to this collection manner.

No processing technology is available. Thus, all collected MSW in their area is sent to disposal site, which is openly dumped (E5). The site is owned by another local authority and the permission is lasted only for another year (E4). MSW management plans are not available (L1, L2). The connection with the public is not yet properly set up. New appropriate disposal site and recovery program is urgently needed. Although public complaint is not reported at present, MSW will soon become a serious problem in the area with increasing amount of generated waste. Accordingly, the long term MSW management plan is being prepared by external party since their planning capability (L1) is insufficient to do it by themselves.

4.5. USER INTERFACE

The assessment tool was developed on Excel worksheet in which local staff is familiar with and it is simple to use. Input interface consists of only two worksheets. Worksheet 1 receives data on the Engineering system, the Public participation, and the Collaboration components while Worksheet 2 receives data on the Local authorities' capability component. These input data are processed to evaluate all aspects. The results are demonstrated through nine worksheets including;

Worksheet 3: Waste information evaluation;

Worksheet 4: Storage performance evaluation (E1);

Worksheet 5: Collection performance evaluation (E2);

Worksheet 6: Processing performance evaluation (E3);

Worksheet 7: Disposal performance evaluation (E4, E5);

Worksheet 8: Environmental impact (E6);

Worksheet 9: Public participation evaluation (P1, P2);

Worksheet 10: Collaboration evaluation (C1, C2, C3, C4); and

Worksheet 11: Sustainability score

The results of L1 and L2 are calculated in Worksheet 2. The detail of each worksheet and their actual interface is presented in Appendix C. However, the user only sees the Worksheet 1 and 2 for inputting data and Worksheet 11 to obtain the analysis result or the sustainability score.

Worksheet 1: User Input#1

In Worksheet 1, user is required to provide all data as listed in Table 4-42. These data can be divided into 10 parts. Common barriers for achieving effective MSW management system in Thailand to be selected include:

- local authorities that are unable to plan appropriate management system
- local authorities that are unable to operate according to the plan
- Implemented technologies are not suitable to local content
- Available budget is not sufficient for constructing and operating
- MSW problem is not priority
- public is not aware of MSW problem
- public is not willing to participate in the system
- appropriate land area is not available for disposal

Data input from Worksheet 1 are used to directly calculate the storage capacity (E1), collection capacity (E2), processing technologies efficiency (E3), disposal land area lifespan (E4), sanitary landfill availability (E5), budget availability (L3), problem priority (L4), public awareness (P1), public willingness (P2), collaboration encouragement (C1), implementation process collaboration (C3), and technical collaboration of local authority (C4).

Table 4-42: Data input of Worksheet 1

Part	Components	Data
1	Demography	Population size (both registered and non-registered)
		Growth rate (% per year)
		Size of responsible area (km^2)
		Number of communities in responsible areas
2	Waste information	Quantity of generated waste (ton/day)
		Generation growth rate (% per year)
		Waste density (kg/m^3)
		Waste composition (% by wet weight)
3	Stakeholders	Activities that each stakeholder is involved
		Proportion of participated public (%)
4	Source separation	Amount of separated organics and recyclables (kg/d)
		Availability of container and truck for separated waste
5	Storage system	Size and number of containers
6	collection system	Size and number of collection truck
		Number of trips and collection frequency
		Quantity of waste collected by each party
7	Processing system	Quantity of waste going to each Processing facility
		Capacity of each Processing facility
		Quantity of recovered and residual from each Processing facility
		Pollution treatment technology of each Processing facility
8	Disposal system	Quantity of waste going to open dump site, landfill
		Size and characteristics of land disposal facility
		Quantity of waste from other local authorities
9	Management finance	Total operating cost
		Total service fee collected
		Total budget for MSW management
10	Management system	Barriers to effective management system

Worksheet 2: User Input#2

Worksheet 2 requires data related to planning activities as summarized in Table 4-43. Data related to six components of the planning system are needed including information management system (IMS), decision support system (DSS), planning management system (PMS), planning supporting system (PSS), planning staff (PS), and administrative system. User is also asked about current situation of their MSW management system which is used to check the data given in Worksheet 1.

Table 4-43: Data input to Worksheet 2

Component	Input Data
Information Management System	Available data are available for planning activities
	Access of the available data
	Format of the available data
Decision Support Subsystem	Available information for making decision
	Criteria used for evaluation
	Decision making process
Planning Output	Involved parties
	Types and contents of available MSW management plans
	Usefulness of available MSW management plans
Planning Management System	Available planning related documents
	Format of the planning related documents
Planning Supporting System	Budget available for planning related activities
	Available planning related facilities
Planning Staff	Number of planning staff
	Provided measures to enhance the performance of planning staff
Administrative System	Supportiveness of administrative structure
Management system	Is collected waste going to your own sanitary landfill
	Are there serious complaints on MSW
	Are new MSW management activities planned to implement

For checking information management system, user is firstly required to check the list of available data related to their current MSW management system in the questionnaire. Number of data regarding each of main categories (storage and collection, recovery for recycling, composting, disposal, and waste characteristics) are later counted and input in the developed assessment tool. Other aspects can be input directly to the developed assessment tool.

Data from the Worksheet 2 are used to calculate the planning system effectiveness (L1), planning system efficiency (L2), planning process collaboration (C2), and technical collaboration of local authority (C4).

Worksheet 9: Overall performance score

Score of each evaluation aspect from Worksheet 3 to 10 are transferred to Worksheet 11. The overall performance score or the sustainability score of analysed MSW management system is determined and presented.

4.6. DISCUSSION

This section discusses the benefit of providing MSW planning support tool in order to improve MSW management system in Thailand.

4.6.1. THE EVALAUTION METHODS

Evaluation method is another issue. Although the calculated sustainability scores of all studied local authorities were satisfied, weaknesses have been found. Adjustment to some methods may be required. The evaluation methods of the Public Participation and Collaboration components were simply checked by asking local staff to identify the related activities that are existing. The analysis result may not be as good as other two components. Mathematical models should be used if more data is available.

It has been found that feasibility study reports are available in many local authorities. These local authorities can use the following evaluation methods with the data from the feasibility study report to calculate the public awareness (P1) for the Public participation component as:

$$\boldsymbol{P1 = \%\ of\ Public\ aware\ of\ MSW\ problem}$$

Moreover, the public willingness (P2) could be adjusted to:

$$\boldsymbol{P2 = \%\ of\ Public\ willing\ to\ participate\ in\ future\ program}$$

A new evaluation aspect – the public willingness to pay (P3) – could also be added, where

$$\boldsymbol{P3 = \%\ of\ Public\ willing\ to\ pay\ for\ the\ provided\ services}$$

The answers to these issues are commonly addressed in the feasibility study. For the Collaboration component, the evaluation method (0 or 1 scheme) of the Collaboration encouragement (C1) may be too rough. Thus, instead of only asking only whether or not the public participation campaign has been promoted, this method could be changed to:

$$\boldsymbol{C1 = \frac{Total\ communities\ that\ local\ authority\ has\ promoted\ the\ participation}{Total\ community\ in\ thier\ responsible\ area}}$$

Because each local authority is responsible for many communities, this method may better reflect the actual situation if the services are not implemented in all communities. Similarly, the evaluation methods of the planning process collaboration (C2) and the implementation process collaboration (C3) could be changed from the implemented activities basis to the proportion of participating community basis. However more data input are required.

The Engineering system component could also be improved. Since the guideline for selecting the location of MSW processing and disposal facilities is available as presented in Table 4-44, taking the guideline into account may better represent the sustainability of MSW management system. As a result, the location suitability could be added to the evaluation of the processing technologies efficiency (E3) as

$$\boldsymbol{E3} = \boldsymbol{Capacity\ sufficiency\ x\ Characteristic\ suitability\ x\ Recovered\ proportion\ x\ Location\ suitability}$$

where;

$$\boldsymbol{Location\ suitability} = \frac{\boldsymbol{Total\ processing\ facilities\ that\ meet\ the\ siting\ guideline}}{\boldsymbol{Total\ implemented\ processing\ facilities}}$$

Table 4-44: Guideline for waste processing technologies location

Technologies	Recommended Criteria
Transfer station and Material Recovery Facilities	- Not located in a watershed area class 1 and 2 under the resolutions relating to the Basin quality on May 28, 1985 - Located not less than 1 kilometer from the historic and ancient places - Located not less than 1 kilometer from the community
Incinerator and Composting facilities	- Not located in a watershed area class 1 and 2 under the resolutions relating to the Basin quality on May 28, 1985 - Located not less than 1 kilometer from the historic and ancient places - Located not less than 1 kilometer from the community - Located in open air area not in the leeward.
Disposal site	- Not located in a watershed area class 1 and 2 under the resolutions relating to the Basin quality on May 28, 1985 - Located not less than 1 kilometer from the historic and ancient places - Located away from the airport boundary not less than 1 kilometer - Located away from drinking wells or water treatment plants not less than meter - Located away from natural or man-made water sources, including the wetland (Wetland) not less than 300 meters, except that the water source is in landfill site

Source: PCD 2001

For landfill, the location suitability could be calculated as

$$\textit{Location suitability of disposal facility} = \frac{\textit{Total the siting guidelines that are met}}{\textit{Total checked siting guidelines}}$$

The result can be added to the availability of sanitary landfill (E5) as

$$\boldsymbol{E5} = \frac{\textbf{\textit{Total implemented sanitary measures}}}{\textbf{\textit{Total recommended sanitary measures}}} \, \textbf{\textit{x Location suitability}}$$

4.6.2. SIGNIFICANCE OF LOCAL AUTHORITY'S PLANNING CAPABILITY TO THE EFFICIENCY OF MSW MANAGEMENT SYSTEM

The significance of local authority's capability on the performance of MSW management system is next discussed to ensure that the improvement would be expected when the developed assessment tool is implemented. The correlation between the calculated planning capability (the summation of the planning effectiveness score (L1) and the planning efficiency score (L2)) of all studied local authorities and the performance level of its MSW management system was consequently checked. If so, the higher planning capability score should result in higher performance level of MSW management system. The result is shown in Figure 4-11.

As expected, the result shows that effective MSW management system (performance level 4 or 5) was achieved in the local authorities with high MSW planning capability. On the other hands, local authorities with low planning capability have inefficient MSW management system (level 0, 1 or 2). The planning capability of local authority thus significantly affects the efficiency of MSW management system. The improvement on the MSW planning system could convincingly enhance the chance of achieving more efficient or sustainable MSW management system.

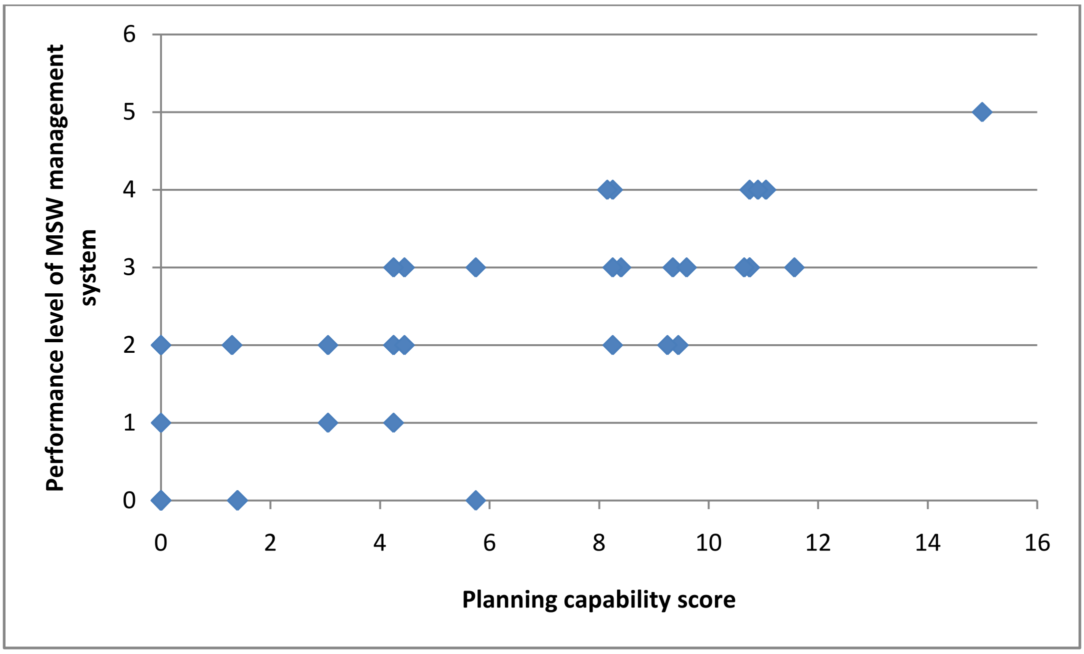


Figure 4-11: The correlation between the calculated planning capability score and the performance level of its MSW management system

However, there are some local authorities with high planning capability that could not achieve MSW management system as effective as other local authorities. The data illustrates that this is because the collaboration with the public of these local authorities are not effective. This evidence is in line with the all three components are contributing to the efficiency of MSW management system.

4.6.3. THE CURRENT MSW PLANNING SYSTEMS OF LOCAL AUTHORITIES IN THAILAND

The data obtained from the first questionnaire is further analysed to determine the current situation of MSW planning capability of local authorities. The planning output of all local authorities are summarised in Table 4-45. Of 329 local authorities, 82 local authorities do not have any types of MSW management plans. That means 75% of studied local authorities have at least one type of MSW management plan which is quite good figure. However, only 4% of them have sound planning output (all three types with all necessary information).

Table 4-45: Planning output of each form of studied local authorities

Planning Output	**Form of Local Authority**				
	Total (329)	**NM (9)**	**MM (48)**	**TM (229)**	**TAO (54)**
Group 1: None	82	0	5	54	23
Group 2: Only Day to day operating plan	70	1	7	48	14
Group 3: Only Project/program	72	4	5	53	10
Group 4: Only Strategy	14	1	3	9	1
Group 5: Day to day operating plan and Project/program,	57	1	9	43	4
Group 6: Day to day operating plan and Strategy	6	0	3	3	0
Group 7: Project/program and Strategy	0	0	0	0	0
Group 8: Day to day operating plan, Project/program, and Strategy	28	2	10	15	1
Group 9: Day to day operating plan, Project/program, and Strategy with all necessary information	11	0	6	4	1

Table 4-45 shows that amongst those that have MSW management plans, most of local authorities studied prepare a day-to-day operating plan (about 50%), followed by a project/program plan (47%) and strategy (15%). These figures are much as expected because preparing an operating plan is less complicated than development of a programme plan or strategy, and such a plan is important for the main duties of an operator.

In addition, only half of those available strategies were prepared by local staff and only 25% contain all necessary information and is considered useful for their implementation. In other words, only 3% of studied local authorities have an appropriate long term plan for their MSW management. This figure has shown the difficulties of achieving long term or sustainable MSW management system in Thailand since only few local authorities have a good strategy to handle MSW problem in their area.

Comparing the planning output of each form of local authorities, (Figure 4-12), Nakhon municipalities and Muang municipalities have produced better planning output than Tambon municipalities and Tambon Administration Organisations as expected. All NMs have at least one type of MSW management plan.

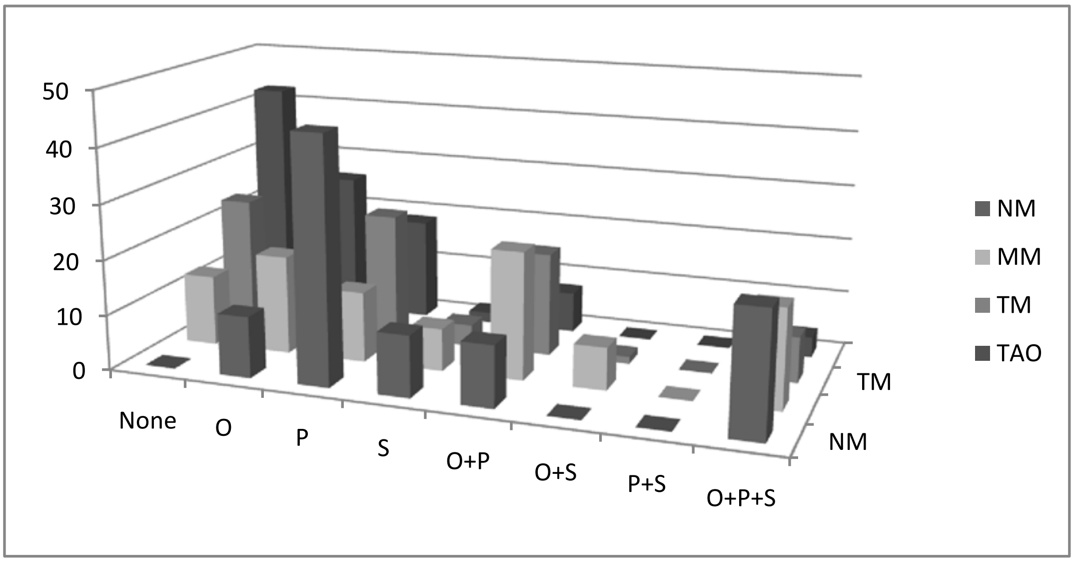


Figure 4-12: Performance of MSW management planning of each form of studied local authorities

Accordingly, more NMs and MMs have all three types of MSW management plans (strategy (S), Program (P), operating plan (O)). This finding illustrated the reliability of collected data. However, the majority of each form has only one type of MSW management plan for handling MSW in their areas, which is not sufficient for achieving sustainable MSW management. Improvement on their planning capability is certainly needed.

Considering the planning step, Table 4-46 shows that the first step (problem diagnosis) and the last step (resource allocation) are most commonly conducted. This is in line with the planning output in which only few local authorities can prepare all three types of MSW management plans and the operating plan is mostly prepared. The result also indicates that these studied local authorities know the basic planning tasks namely diagnosing the problem and allocating resources to address it. However, the quality of conducting these planning steps is doubtful.

Table 4-46: Undertaken planning step of preliminary studied local authorities

Planning Step	**Form of Local Authority**				
	Total (329)	**NM (9)**	**MM (48)**	**TM (229)**	**TAO (54)**
Step 1: Diagnose problem	**245**	9	23	179	34
Step 2: Define causes	**203**	9	19	144	31
Step 3: Set up objectives	**184**	9	17	132	26
Step 4: Project waste quantity and composition	**200**	9	18	147	26
Step 5: Formulate choices of strategies	**105**	7	11	76	11
Step 6: Evaluate each choice of strategies	**95**	6	11	63	15
Step 7: Set up targets	**93**	5	8	69	11
Step 8: Set up implementation schedule	**139**	8	11	101	19
Step 9: Allocate resources	**218**	9	14	156	39

The steps that are least conducted are the sixth step (alternative analysis) and seventh step (target set up). The result meets the assumption that MSW operational management system proposed to implement in their area is often imitated the city which is reasonably successful without comprehensive evaluation whether such system is suitable to their current situation which may fail in their city. Because of this, it was strongly suspected that the first planning step was not efficiently carried out as the analysis content was similar to the sixth step. Thus, the proposed planning tool will be highly beneficial to MSW planning process in local authorities.

The collected data also shows that 77% of studied local authorities have planning staff. Regarding planning supporting resources, fundamental requirements that are considered necessary for effective MSW planning these days are budgets (for running the planning activities, training corresponding staff, and acquiring planning facilities), computer facility, planning software, and planning manual. Availability of these resources was also checked and the result is given in Table 4-47.

Table 4-47: Planning facilities of studied local authorities

Planning Resources	**Form of Local Authority**				
	Total (329)	**NM (9)**	**MM (48)**	**TM (229)**	**TAO (54)**
Budget for running the planning activities	91	3	7	68	13
Budget for training corresponding staff	181	6	16	133	26
Budget for acquiring planning facilities	97	3	7	75	12
Computer facilities	195	9	20	143	23
Planning related software	16	3	0	11	2
Planning related manual	107	3	11	83	10

As can be seen from the table, about 60% of studied local authorities have budget for their planning activities and computer facility. However, only few or 5% have planning related software to assist then in such a complex process. Unfortunately, the type and application of these available planning software was not asked in the questionnaire. The development of planning support tool would thus greatly help to enhance the planning capability of local authorities and consequently MSW management in Thailand.

4.7. CONCLUSION

At present, the majority (95%) of the studied local authorities in Thailand are unable to conduct proper MSW planning process in order to design MSW management system. Only few local authorities produced comprehensive MSW management plans, which is essential for handling their generated MSW effectively. Improvement measures are required. Based on Thai experience, a proper MSW planning system consists of six key components including planning staff (PS), planning (PSS) and decision support systems (DSS), information (IMS) and planning management systems (PMS), and supporting administrative structures (AS). These components are inter-related and support each other. Deficiency in any of the components affects the entire MSW planning system. Comprehensive MSW management plans are produced from the planning system having these six components in good conditions.

Unfortunately, only few local authorities in Thailand have such planning system. However, most of studied local authorities (77%) have planning staff but not planning support facilities particularly planning support tool. Attention should be paid to this issue. Regarding the current planning manner, the problem diagnosis and evaluation, which is the most important planning step to design corrective actions for moving towards sustainable MSW management system, was not carried out in a proper manner by local authorities in Thailand.

Thus, the developed assessment tool was designed to assist local authorities evaluating the existing MSW management system based on the concept of sustainable MSW management system. Sustainable MSW management should be ***Sufficient, Continuous, Sanitary, for Long term*** and can be managed with ***available local knowledge, resources and wisdom*.** Therefore, the developed assessment tool evaluates four main components significantly contributing to the sustainability of MSW management.

These include the engineering system, local authority's capability, the public participation, and the collaboration, containing 16 evaluation aspects. Current practices illustrated that the engineering system, the local authorities' capability, the public participation, and the collaboration are all important to the effectiveness or sustainability of MSW management system. The methods proposed to determine the sustainability score of MSW management system was well correlated with the actual practices. Using the developed assessment tool will then significantly help local authorities to evaluate the performance of existing MSW management more precisely. The current practice also illustrated that the improved planning capability enhanced the chance of achieving more effective or sustainable MSW management system.

CHAPTER 5

CONCLUSION AND FUTURE WORK

The main objective of this research is to develop a new computer-based tool to assess the performance of current MSW management system subject to the sustainable conditions, common goal for MSW management at present. Their planning capability can be enhanced in order to improve the efficiency of MSW management system. The research hypothesis is that – *the improvement of MSW planning systems of local authorities would enhance their planning capabilities and subsequently MSW management system. In doing so, a new suitable support tool should be provided.* MSW management system systematically designed to suite local problem and condition is expected.

This new assessment tool assists local authority in evaluating the existing MSW management system and presents the score, illustrating the status of current MSW management system as compared with the sustainability goal. The gap for achieving sustainable MSW management system is revealed. There is no MSW planning support tool with such feature available at present. With the developed assessment tool, the local staff should be able to design more effective MSW management system for their area in order to decrease the gap and move towards sustainable MSW management system. The developed assessment tool is also expected to be useful for other developing countries, having similar problem to Thailand.

5.1. THE NEW MSW ASSESSMENT TOOL

The developed assessment tool named **PATHWAY** - **P**lanning **A**ssessment tool for **TH**ailand **WA**ste sustainabilit**Y** is designed to evaluate the sustainability level of current MSW management system being implemented in their areas which is considered as the most important step for obtaining appropriate actions to achieve effective MSW management system. PATHWAY is developed on Excel Worksheet which is easy to use by local authorities in Thailand. The output of PATHWAY is a score indicating the sustainability level. MSW management system with higher score tends to handle their MSW better than others in a long term.

Sustainable MSW management system is defined in this research as the system that is ***sufficient, regular, and sanitary for long term*** and can be managed with ***available local knowledge, resources and wisdom.*** Accordingly, PATHWAY evaluates four main components which were proven in this study to contribute significantly to the sustainability of MSW management. These include the Engineering system (ES), Local authority's capability (LAC), Public participation (PP), and Collaboration (CB). Each evaluation component consists of evaluation aspects. The sustainability score of MSW management system is calculated and equal to the summation of each component score as:

$$\boldsymbol{Sustainability\,Score = ES + LAC + PP + CB}$$

The sustainability score calculated by the developed evaluation methods (both evaluation aspects and calculation methods) of the proposed assessment tool is well correlated with the actual performance level of exiting MSW management system in Thailand. The calculated sustainability score can also indicate the efficiency level of any MSW management system. Importantly, the data that are required to put into the developed assessment tool is available at any levels of local authorities, even Tambon Administrative Organisation, the lowest level.

5.1.1. EVALUATION ASPECTS

All key conditions needed to support the efficiency of MSW management system are evaluated. Evaluation aspects of each evaluation component are summarised in Table 5-1. For the Engineering system component, the performance of main MSW management activities are evaluated including source separation, source storage, collection system, central processing technologies, and disposal processes. The developed assessment tool checks whether all generated waste is properly stored (E1) and collected (E2), these collected waste is transferred to appropriate processing facilities (E3) to reduce the amount going to final disposal which is sufficient for waste generated in the next 20 years (E4) and environmentally friendly (E5). The environmental performance of the entire MSW management system (E6) is also checked.

Table 5-1: Evaluation aspects of the developed assessment tool

Evaluation Components	Evaluation Aspects
Engineering System (ES)	∉ Storage capacity (E1)
	∉ Collection efficiency (E2)
	∉ Processing technologies efficiency (E3)
	∉ Lifespan of available disposal area (E4)
	∉ Availability of sanitary landfill (E5)
	∉ Environmental impact (E6)
Local authorities' Capability (LAC)	∉ Planning system effectiveness (L1)
	∉ Planning system efficiency (L2)
	∉ Budget availability (L3)
	∉ Problem priority (L4)
Public Participation (PP)	∉ Public awareness (P1)
	∉ Public willingness (P2)
Collaboration (CB)	∉ Collaboration encouragement (C1)
	∉ Planning process collaboration (C2)
	∉ Implementation process collaboration (C3)
	∉ Technical collaboration of local authority (C4)

The assessment tool next checks the capability of local authority to handle MSW situation. Each local authority should have effective planning system (L1) in their organisation and the available planning system should work efficiently (L2) in order to design appropriate MSW management by themselves. Once the MSW management system is planned and implemented, the available budget should be sufficient (L3) to continue the operation. Importantly, MSW problem should be their priority (L4).

Another key player of efficient MSW management system is the public and their collaboration with local authority. Sustainable MSW management system can be achieved only when public see MSW problem as an important issue (P1) and is willing to participate in any activities (P2). On the other hand, local authority should encourage and welcome these local people in the management process (C1). Public should be involved in both planning (C2) and implementation process (C3) as they are a direct user. The selected system should be in relation with their willing. Overall, it is important for any area that local authority can efficiently handle the implemented MSW management system (C4). The developed assessment tool checks all these conditions.

5.1.2. EVALUATION METHODS

The evaluation methods are designed to compare the current performance of those four components to the appropriate conditions mentioned above. Complex mathematical analysis is avoided concerning the limitation of local authorities in Thailand. These developed evaluation methods well represent the current status of MSW management system subject to the sustainability goal.

5.1.2.1. ENGINEERING SYSTEM COMPONENT (ES)

Main activities of MSW management are evaluated including source separation, source storage, collection, central processing technologies, and disposal processes. Environmental impact evaluation is also included in this component.

5.1.2.1.1. Storage capacity (E1)

The volume of provided containers is compared with the generated waste volume.

$$\boldsymbol{E1 = \frac{Total\ container\ volume\ (m^3)}{Total\ generated\ waste\ volume\ (m^3)}}$$

5.1.2.1.2. Collection efficiency (E2)

The capacity of collection vehicles is compared with the waste volume to be collected.

$$\boldsymbol{E2 = \frac{Total\ collection\ truck\ volume\ (\frac{m^3}{day})}{Total\ generated\ waste\ volume\ (\frac{m^3}{day})}}$$

5.1.2.1.3. Processing technologies efficiency (E3)

The suitability of implemented processing technologies to the quantity and characteristics of incoming waste and their effectiveness are checked. The effectiveness refers to the proportion of incoming waste quantity as compared with the quantity of recoverable waste.

$$\boldsymbol{E3 = Capacity\ sufficiency\ x\ Characteristic\ suitability\ x\ Recovered\ Proportion}$$

5.1.2.1.4. Lifespan of available disposal area (E4)

The lifespan of available disposal site is checked whether the area is sufficient for waste generated over the next 20 years.

$$E4 = \frac{Lifespan\ of\ current\ disposal\ site\ (yrs)}{Expected\ Lifespan\ (20\ yrs)}$$

5.1.2.1.5. Availability of sanitary landfill (E5)

This aspect checks the sanitary measures that have been implemented at the disposal site. Five measures are checked.

$$E5 = \frac{Total\ implemented\ sanitary\ measures}{Total\ recommended\ sanitary\ measures}$$

5.1.2.1.6. Environmental impact (E6)

The environmental impacts of four main activities are checked including storage process, collection process, processing facilities, and disposal process. Each activity is considered sanitised when all generated waste is stored in provided containers, all stored waste is collected on the collection day, proper pollution treatment system is installed, and sanitary landfill exist respectively. Thus;

$$E6 = \frac{Total\ sanitised\ management\ activities}{Total\ checked\ management\ activities}$$

5.1.2.2. LOCAL AUTHORITY'S CAPABILITY COMPONENT (LAC)

Both planning and implementation capabilities of local authorities are evaluated.

5.1.2.2.1. Planning system effectiveness (L1)

The planning system effectiveness is equal to

$$\boldsymbol{L1 = PS + PSS + DSS + IMS + PMS + AS}$$

Where PS = the score of planning staff (PS)
PSS = the score of planning support system (PSS)
DSS = the score of decision support system (DSS)
IMS = the score of information management system (IMS)
PMS = the score of planning management system (PMS)
AS = the score of administrative structure (AS)

5.1.2.2.2. Planning system efficiency (L2)

The score of planning system effectiveness is used to predict the types of MSW management that local authority should be able to develop. The result is compared with the types of MSW management plans that are actually developed. Thus, the planning system efficiency (L2) is calculated as:

$$\boldsymbol{L2 = \frac{Number\ of\ MSW\ management\ plans\ actually\ prepared}{Number\ of\ MSW\ management\ plans\ that\ should\ be\ prepared}}$$

5.1.2.2.3. Budget availability (L3)

The sufficiency of annual budget for system operation is evaluated to check the implementation capability.

$$\boldsymbol{L3 = \frac{Available\ annual\ operating\ budget}{Required\ operating\ cost}}$$

5.1.2.2.4. Problem priority (L4)

The existing of activities intrinsically illustrating that local authority is giving attention to MSW problem is checked. Five activities are checked including:

1. Local authority has campaign to encourage source separation
2. Container is provided for source separated waste
3. Collection vehicle is provided for separated waste
4. Solid waste is one of environmental policy
5. Local authority looks for new method for MSW

$$\boldsymbol{L4 = \frac{Total\ implemented\ activities}{Total\ checked\ activities}}$$

5.1.2.3. PUBLIC PARTICIPATION COMPONENT (PP)

Awareness and willingness to participate of the public are checked.

5.1.2.3.1. Public awareness (P1)

Local authority is asked whether public is participating in source separation campaign and is greatly aware of MSW issue. If both circumstances are available, P1 is equal to 1. If only one circumstance is available, P1 is equal to 0.5, otherwise equal to 0. Thus,

$$\boldsymbol{P1 = 0, 0.5, 1}$$

5.1.2.3.2. Public willingness (P2)

Local authority is asked to check four activities that the public should involve themselves in. These activities are

1. public involve in the collection process
2. public involve in source separation for recycling
3. public involve in source separation for central or home composting processes
4. unwilling public is not the problem for managing MSW in the area

Therefore:

$$\boldsymbol{P2 = \frac{Total\ activities\ that\ public\ involved\ themselves\ in}{Total\ checked\ activities}}$$

5.1.2.4. COLLABORATION COMPONENT (CB)

Fundamental activities indicating the collaboration between local authority and public are checked. Evaluation methods of this component may need adjustment in the future.

5.1.2.4.1. Collaboration encouragement (C1)

Local authority is asked to check the promotion of MSW management participation campaign. If the participation campaign has been promoted, C1 is equal to 1, otherwise equal to 0.

$$\boldsymbol{C1 = 0, 1}$$

5.1.2.4.2. Planning process collaboration (C2)

Local authority is asked to check three planning related activities that public has been participated.

$$\boldsymbol{C2} = \frac{\boldsymbol{Total\ planning\ activities\ that\ public\ involved\ themselves\ in}}{\boldsymbol{Total\ checked\ planning\ activities}}$$

5.1.2.4.3. Implementation process collaboration (C3)

Local authority is asked to check four operating activities that both local authority and public are participating.

$$\boldsymbol{C3} = \frac{\boldsymbol{Total\ operating\ activities\ that\ public\ involved\ themselves\ in}}{\boldsymbol{Total\ checked\ operating\ activiites}}$$

5.1.2.4.4. Technical collaboration of local authority (C4)

The conditions indicating that local authority can work with the operating MSW management system are checked.

$$\boldsymbol{C4} = \frac{\boldsymbol{Total\ conditions\ of\ efficient\ MSW\ management\ system\ that\ exist}}{\boldsymbol{Total\ checked\ conditions}}$$

5.2. BENEFIT OF NEW ASSESSMENT TOOL PROVISION

Only a few of studied local authorities (4%) are currently able to prepare three types of MSW management plans including strategy, programme plan, and operating plan containing all information necessary for implementation. Most of local authorities studied prepare an operating plan while a strategy or long term plan is least prepared. In addition, only 3% of studied local authorities have an appropriate long term plan for their MSW management.

Accordingly, only few carry out all necessary planning steps. Measures are required to address the deficit or to establish more effective MSW planning system in local authorities in Thailand. The first planning step (problem diagnosis) and the last planning step (resource allocation) are most commonly conducted. This indicates that these studied local authorities know the basic planning tasks namely diagnosing the problem and allocating resources to address it. These steps are not carried out efficiently. Providing the developed assessment tool would enhance the quality of these steps.

The study result also illustrates that planning staff, planning support system, and decision support system are fundamental requirement for starting up a effective MSW planning system, and that, of these, planning staff is the most important component, followed by planning support system. However, the study has found that 77% of studied local authorities have planning staff but only 5% have planning related software to assist them in complex planning process although about 60% have budget available for their planning activities and facility. This finding confirms the great opportunity to improve the MSW management planning system of local authorities if the developed assessment tool is provided.

The study also shows the evidences that effective MSW management system is achieved in the local authorities with high MSW planning capability and vice versa. The improvement on the MSW planning system is thus believed to consequently enhance the chance of achieving more efficient or sustainable MSW management system at local level.

5.3. FUTURE STUDY

Although the developed assessment tool or PATHWAY provides reliable sustainability score of analysed MSW management system, weaknesses are found.

Adjustment can be made in the future. The quantitative methods should be developed for the Public participation component and collaboration component. The evaluation methods of the following evaluation aspects can be improved.

- the public awareness (P1)
- the public willingness (P2)
- the collaboration encouragement (C1)
- the planning process collaboration (C2)
- the implementation process collaboration (C3)

However, the ability of local authorities to acquire input data must be primarily concerned. Otherwise, the local staff will hesitate to use the developed tool.

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APPENDIX A

The first questionnaire

การศึกษาระบบการวางแผนการจัดการขยะมูลฝอยชุมชนขององค์กรปกครองท้องถิ่นประเทศไทย

แบบสอบถาม

กรุณาส่งแบบสอบถามคืน ไปที่

อาจารย์จรีรัตน์ สกุลรัตน์
ภาควิชาวิศวกรรมโยธา
มหาวิทยาลัยสงขลานครินทร์ วิทยาเขตหาดใหญ่
ตำบลคอหงส์ อำเภอหาดใหญ่ จังหวัดสงขลา 90112

1. รายละเอียดของหน่วยงาน

1.1. ลักษณะการบริหารขององค์กรท่านเป็นแบบใด (โปรดกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม)

☐ เทศบาลนคร ☐ เทศบาลเมือง ☐ เทศบาลตำบล ☐ องค์การบริหารส่วนตำบล

1.2. ท่านทำงานอยู่ในส่วนใด (เช่น กองสาธารณสุขและสิ่งแวดล้อม, กองช่าง) ____________________

1.3. ส่วนของท่านรับผิดชอบงานด้านใด

☐ งานเก็บรวบรวมและขนส่ง ☐ งานคัดแยกเพื่อนำกลับไปใช้ใหม่

☐ งานหมักทำปุ๋ย ☐ งานเผาในเตาเผา ☐ งานฝังกลบ

2. ประสิทธิภาพของระบบการจัดการขยะมูลฝอยในปัจจุบัน

2.1. ขนาดพื้นที่รับผิดชอบ __________ (ตร.กม.) ประชากรในพื้นที่รับผิดชอบ __________ (คน)

2.2. ประสิทธิภาพของระบบการจัดการ

2.2.1. จำนวนถังรองรับมูลฝอย __________ ใบ

2.2.2. จำนวนรถเก็บขนมูลฝอย __________ คัน

2.2.3. ปริมาณขยะมูลฝอยที่เก็บขนได้ในแต่ละวัน __________ (ตัน/วัน)

2.2.4. ปริมาณขยะที่ฝังกลบอย่างถูกสุขลักษณะ __________ (ตัน/วัน)

2.2.5. ปริมาณขยะที่คัดแยกเพื่อนำกลับมาใช้ใหม่ __________ (ตัน/วัน)

2.2.6. ปริมาณขยะที่หมักทำปุ๋ย __________ (ตัน/วัน)

2.2.7. ปริมาณขยะที่เผาในเตาเผา __________ (ตัน/วัน)

3. ประสิทธิภาพของการวางแผนและออกแบบระบบการจัดการขยะมูลฝอยในปัจจุบัน

3.1. ขั้นตอนการวางแผน

3.1.1. ขั้นตอนใดต่อไปนี้ที่ท่านใช้ในการเตรียมแผนและออกแบบระบบการจัดการขยะมูลฝอยชุมชน

☐ วิเคราะห์ปัญหาของระบบการจัดการในปัจจุบัน

☐ วิเคราะห์หาสาเหตุของปัญหา

☐ วางเป้าหมายของระบบการจัดการที่ต้องการ (ระยะยาว หรือ กลาง)

☐ วิเคราะห์ขยะมูลฝอยที่รับผิดชอบ (ปริมาณ, องค์ประกอบ, อัตราการเกิด/การเพิ่ม)

☐ ออกแบบทางเลือกในการจัดการขยะในพื้นที่ให้บรรลุตามเป้าหมายที่วางไว้ เพื่อทำแผนกลยุทธ์ (แผนระยะยาว 7 – 20 ปี)

☐ วิเคราะห์ประสิทธิภาพของแต่ละทางเลือกในการบรรลุเป้าหมายที่วางไว้

☐ แจงรายละเอียดของงานที่ต้องปฏิบัติเพื่อบรรลุงานที่วางไว้ในแผนกลยุทธ์ที่เลือก เพื่อทำแผนระยะกลาง หรือ สั้น (1 – 7 ปี)

☐ กำหนดเวลาในการปฏิบัติแต่ละงานในแผนระยะกลาง หรือ สั้น

☐ กำหนดบุคลากร อุปกรณ์ และงบประมาณในการปฏิบัติแต่ละงานในแผนระยะกลาง หรือ สั้น

3.2. ระบบการจัดการข้อมูล

3.2.1. หน่วยงานท่านมีข้อมูลใดต่อไปนี้บ้างเพื่อเตรียมแผนการจัดการขยะมูลฝอยชุมชน

3.2.1.1. การกักเก็บ ณ แหล่งกำเนิด

- ☐ จำนวนครัวเรือนในพื้นที่รับผิดชอบ
- ☐ จำนวนครัวเรือนที่ได้รับบริการ (สามารถเข้าถึงถังขยะที่จัดให้ได้)
- ☐ ปริมาณขยะที่เกิดขึ้นทั้งหมดในพื้นที่รับผิดชอบ
- ☐ ปริมาณขยะที่เก็บขนได้ในแต่ละวัน (ตัน/วัน)
- ☐ เป้าหมายในการจัดเก็บ (% ของขยะทั้งหมดที่เกิดขึ้น)
- ☐ ค่าใช้จ่ายในการเก็บขน (บาท/ตัน)
- ☐ ปริมาณขยะที่แต่ละจุดเก็บขน (กก.)
- ☐ จำนวนถังขยะที่จัดไว้ที่แต่ละจุดเก็บขน (ใบ)
- ☐ ขนาดของถังขยะที่มีอยู่ (ลิตร)
- ☐ เวลาที่ใช้ในการถ่ายถังขยะแต่ละใบ (นาที)

3.2.1.2. การเก็บขน

- ☐ ปริมาณขยะที่ต้องเก็บในแต่ละเส้นทางของรถเก็บขน (ตัน)
- ☐ จำนวนจุดเก็บขนในแต่ละเส้นทาง
- ☐ ขนาดของรถเก็บขนขยะแต่ละคัน (ลบ.ม.)
- ☐ เวลาที่ใช้ในการเก็บขนแต่ละเที่ยวของรถเก็บขนแต่ละคัน (ชม./เที่ยว)
- ☐ จำนวนเที่ยวในการเก็บขนของรถแต่ละคัน (เที่ยว/คัน)
- ☐ จำนวนชั่วโมงทำงานที่ใช้จริงของแต่ละทีมเก็บขน (ชม./วัน)
- ☐ ขนาดพื้นที่รับผิดชอบของพนักงานเก็บกวาดแต่ละคน (ตร.ม.)
- ☐ ปริมาณขยะที่ต้องเก็บโดยพนักงานเก็บกวาดแต่ละคน (กก.)
- ☐ จำนวนชั่วโมงทำงานที่กำหนดให้พนักงานเก็บกวาด (ชม./วัน)
- ☐ จำนวนชั่วโมงทำงานที่ใช้จริงของพนักงานเก็บกวาดแต่ละคน (ชม./วัน)

3.2.1.3. การนำขยะกลับไปรีไซเคิล

- ☐ ปริมาณขยะทั้งหมดที่คัดแยกเพื่อนำกลับไปใช้ใหม่ (กก.)
- ☐ เป้าหมายในการคัดแยกขยะที่นำกลับไปใช้ใหม่ได้ (% ของขยะที่เก็บได้)
- ☐ ปริมาณขยะแต่ละประเภทที่คัดแยกได้ (กก.)
- ☐ ปริมาณขยะแต่ละประเภทที่คัดแยกได้ที่นำไปรีไซเคิล (กก.)
- ☐ ค่าใช้จ่ายทั้งหมดในการคัดแยกขยะ (บาท/กก.)
- ☐ รายได้ที่ได้จากขยะที่คัดแยกได้ (บาท/กก.)

3.2.1.4. การนำขยะไปทำปุ๋ย

- ☐ องค์ประกอบทางกายภาพของขยะที่นำมาหมักทำปุ๋ย
- ☐ องค์ประกอบทางเคมีของขยะที่นำมาหมักทำปุ๋ย
- ☐ ปริมาณขยะที่เข้ามาที่สถานที่หมักทำปุ๋ย (กก./วัน)
- ☐ ความจุของสถานที่กักขยะเพื่อหมักทำปุ๋ย (กก.)
- ☐ ปริมาณปุ๋ยที่ผลิตได้ในแต่ละวัน (กก./วัน)
- ☐ คุณภาพของปุ๋ยที่ผลิตได้
- ☐ ปริมาณของเสียที่เกิดขึ้นจากสถานที่หมักทำปุ๋ย (กก./วัน)
- ☐ ปริมาณกากที่เหลือเพื่อฝังกลบ (กก.)
- ☐ ค่าใช้จ่ายทั้งหมดในการหมักทำปุ๋ย (บาท/กก.)
- ☐ รายได้จากการจำหน่ายปุ๋ยที่ผลิตได้ (บาท/กก.)

3.2.1.5. การนำขยะไปเผาในเตาเผา

- ☐ องค์ประกอบทางกายภาพของขยะที่นำมาเผาในเตาเผา
- ☐ องค์ประกอบทางเคมีของขยะที่นำมาเผาในเตาเผา
- ☐ ปริมาณขยะที่เข้ามาที่เตาเผา (กก./วัน)
- ☐ ความจุของสถานที่กักขยะเพื่อเข้าเตาเผา (กก.)
- ☐ ปริมาณขยะเผาได้ในแต่ละวัน (กก./วัน)
- ☐ ปริมาณกากที่เหลือเพื่อฝังกลบ (กก./วัน)
- ☐ กระแสไฟฟ้าที่สามารถผลิตได้
- ☐ ปริมาณมลพิษที่เกิดขึ้นจากเตาเผา
- ☐ ค่าใช้จ่ายทั้งหมดในการเผาขยะ (บาท/ตัน)
- ☐ รายได้จากการผลิตกระแสไฟฟ้า (บาท/ตัน)

3.2.1.6. การนำขยะไปฝังกลบ

- ☐ อายุการใช้งานของหลุมฝังกลบ (ปี)
- ☐ ปริมาณขยะทั้งหมดที่เข้ามาที่หลุมฝังกลบแต่ละวัน (ตัน/วัน)
- ☐ ปริมาณมลพิษที่เกิดขึ้นจากหลุมฝังกลบ
- ☐ อัตราการเกิดมูลฝอยต่อคนต่อวัน (กก./คน/วัน)
- ☐ อัตราการเติบโตของประชากรในพื้นที่รับผิดชอบ (%/ปี)
- ☐ อัตราการเพิ่มของขยะในแต่ละปี (ตัน/ปี)
- ☐ องค์ประกอบทางกายภาพของขยะ
- ☐ องค์ประกอบทางเคมีของขยะ

3.2.2. ข้อมูลเหล่านี้ถูกจัดเก็บไว้ในที่เดียวกันหรือไม่ ☐ ใช่ ☐ ไม่ใช่

3.2.3. ข้อมูลที่มีนี้สามารถเรียกใช้ได้อย่างสะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

3.2.4. ข้อมูลเหล่าถูกจัดเก็บอยู่ในรูปแบบใดบ้าง ☐ เอกสาร ☐ แฟ้มข้อมูลในคอมพิวเตอร์

3.3. ระบบการตัดสินใจเลือกระบบการจัดการขยะมูลฝอยชุมชนที่เหมาะสม

3.3.1. ท่านมีรายละเอียดใดบ้างก่อนการตัดสินเลือกระบบการจัดการที่ต้องการ

☐ ประสิทธิภาพของระบบการจัดการในปัจจุบัน ☐ ประสิทธิภาพของแต่ละแนวทางเลือกที่ออกแบบไว้

3.3.2. หลักเกณฑ์ใดที่ใช้พิจารณาเลือกระบบการจัดการที่เหมาะสม

☐ ประสิทธิภาพ ☐ ผลกระทบทางสิ่งแวดล้อม

☐ เศรษฐศาสตร์ และการเงิน ☐ ผลกระทบทางสังคม

3.3.3. ขั้นตอนการวางแผนใดมีการใช้เครื่องมือช่วย (เช่น โปรแกรมคอมพิวเตอร์)

☐ วิเคราะห์ปัญหาของระบบการจัดการในปัจจุบัน ☐ ออกแบบทางเลือกของแผนกลยุทธ์เพื่อแก้ปัญหาที่เกิดขึ้น

☐ วิเคราะห์ประสิทธิภาพของแต่ละทางเลือก

3.3.4. มีการประชุมในหน่วยของท่านก่อนการตัดสินเลือกระบบการจัดการที่เหมาะสมหรือไม่ ☐ มี ☐ ไม่มี

3.3.5. มีการสอบถามความคิดเห็นประชาชนในพื้นที่ก่อนการตัดสินใจหรือไม่ ☐ มี ☐ ไม่มี

3.4. ระบบการจัดการแผน

3.4.1. ท่านมีแผนประเภทใดบ้างในการจัดการขยะมูลฝอยชุมชน

☐ แผนกลยุทธ์ (ระยะ 7 – 20 ปี) โปรดตอบคำถามที่ 3.4.1.1 – 3.4.1.4

☐ แผนระยะกลาง หรือ สั้น (ระยะ 1 – 7 ปี) โปรดตอบคำถามที่ 3.4.1.5 – 3.4.1.8

☐ แผนปฏิบัติการประจำวัน โปรดตอบคำถามที่ 3.4.1.9 – 3.4.1.12

☐ ไม่มี โปรดข้ามไปที่คำถาม 3.5.1

3.4.1.1. ใครเป็นผู้เตรียมแผนกลยุทธ์ ☐ เจ้าหน้าที่ในองค์กร ☐ หน่วยงานภายนอก เช่น บริษัทที่ปรึกษา

3.4.1.2. ประเด็นใดบ้างที่อยู่ในแผนกลยุทธ์

☐ สภาพทั่วไปของพื้นที่รับผิดชอบ (เช่น โครงสร้างเศรษฐกิจและสังคม, ประชากร, ปริมาณขยะ)

☐ เป้าหมายหรือหลักการของระบบการจัดการมูลฝอยที่ออกแบบ

☐ องค์ประกอบของระบบการจัดการทั้งหมด เช่น ระบบการจัดเก็บ, คัดแยก, ฝังกลบ

☐ รายละเอียดของแต่ละองค์ประกอบของระบบการจัดการ

☐ แผนการดำเนินการ

☐ เทคโนโลยีที่ใช้ในแต่ละองค์ประกอบของระบบการจัดการ

3.4.1.3. แผนกลยุทธ์นี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือ ☐ สะดวก ☐ ไม่สะดวก

3.4.1.4. แผนกลยุทธ์นี้เสนอข้อมูลที่เป็นประโยชน์ต่อการจัดการขยะในปัจจุบันหรือไม่

☐ ใช่ ☐ ไม่ใช่, โปรดอธิบาย ______________________________

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3.4.1.5. ใครเป็นผู้เตรียมแผนระยะกลางหรือสั้น ☐ เจ้าหน้าที่ในองค์กร ☐ หน่วยงานภายนอก เช่น บริษัทที่ปรึกษา

3.4.1.6. ประเด็นใดบ้างที่อยู่ในแผนโครงการ

☐ เป้าหมายของโครงการ ☐ ระยะเวลาโครงการ
☐ วิธีการดำเนินการ ☐ อุปกรณ์ เครื่องมือที่ต้องการสำหรับโครงการ
☐ บุคลากรที่ต้องการ ☐ งบประมาณที่ต้องการ
☐ ตัวชี้วัดประสิทธิภาพของโครงการ

3.4.1.7. แผนโครงการนี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

3.4.1.8. แผนโครงการนี้เสนอข้อมูลที่เป็นประโยชน์ต่อการจัดการขยะในปัจจุบันหรือไม่

☐ ใช่ ☐ ไม่ใช่, โปรดอธิบาย ______________________________

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3.4.1.9. ใครเป็นผู้เตรียมแผนปฏิบัติการประจำวัน ☐ เจ้าหน้าที่ในองค์กร ☐ หน่วยงานภายนอก เช่น บริษัทที่ปรึกษา

3.4.1.10. ประเด็นใดบ้างที่อยู่ในแผนปฏิบัติการประจำวัน

☐ รายละเอียดของงานที่ต้องปฏบัติในแต่ละวัน
☐ ตารางเวลาการปฏิบัติงาน
☐ บุคลากรในการปฏิบัติแต่ละงาน
☐ อุปกรณ์ในการปฏิบัติแต่ละงาน

3.4.1.11. แผนปฏิบัติการนี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

3.4.1.12. แผนปฏิบัติการนี้เสนอข้อมูลที่เป็นประโยชน์ต่อการจัดการขยะในปัจจุบันหรือไม่

☐ ใช่ ☐ ไม่ใช่, โปรดอธิบาย ______________________________

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3.5. ระบบการจัดการระบบการวางแผน

3.5.1. ท่านมีเอกสารแสดงรายละเอียดใดบ้าง

☐ ขั้นตอนการวางแผน ☐ วิธีการจัดการระบบการวางแผน
☐ วิธีการจัดการข้อมูล ☐ รายชื่อผู้เกียวข้องในแต่ละงานด้านการเตรียมแผน
☐ วิธีการเลือกระบบการจัดการที่เหมาะสม ☐ ตารางเวลาในการเตรียมแผนการจัดการ
☐ วิธีการจัดการแผนการจัดการ

3.5.2. เอกสารเหล่านี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

3.6. ทรัพยากร

3.6.1. มีค่าใช้จ่ายเฉพาะสำหรับกิจกรรมใดบ้าง

☐ การเตรียมแผนการจัดการ ☐ การอบรมบุคลากรที่เกี่ยวข้องในเรื่องการออกแบบแผน

☐ จัดซื้อเครื่องมือ อุปกรณ์ ที่เกี่ยวข้องกับการวางแผน

3.6.2. ท่านมีอุปกรณ์เหล่านี้ในการวางแผนหรือไม่ ☐ คอมพิวเตอร์ ☐ ซอฟแวร์ ☐ คู่มือ

3.7. บุคลากร

3.7.1. จำนวนเจ้าหน้าที่ทั้งหมดที่เกี่ยวข้องกับการเตรียมแผนและออกแบบระบบการจัดการมูลฝอย ________ คน

3.7.2. มีการจัดอบรมเพื่อเพิ่มความรู้ด้านการวางแผนให้กับเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ มี ☐ ไม่มี

3.7.3. มีกลไกในการส่งเสริมความตั้งใจในการทำงานของเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ มี ☐ ไม่มี

3.7.4. มีการแจงรายละเอียดของงานต่อเจ้าหน้าที่เหล่านี้ก่อนการทำงานหรือไม่ ☐ มี ☐ ไม่มี

3.8. โครงสร้างการบริหารขององค์กร

3.8.1. จำนวนเจ้าหน้าที่ในส่วนของท่านทั้งหมด ________ คน (ไม่รวมพนักงานเก็บขนและกำจัดมูลฝอย)

3.8.2. งานอื่นๆ ที่ต้องทำนอกเหนือจากงานที่เกี่ยวข้องกับระบบการจัดการ ________________________________

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3.7.5. โครงสร้างบริหารในปัจจุบันให้ความสะดวกในการออกแบบระบบการจัดการหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

ขอขอบคุณในการร่วมมือตอบแบบสอบถาม

The second questionnaire

การศึกษาความยั่งยืนของระบบการจัดการขยะชุมชนขององค์กรท้องถิ่น ประเทศไทย

แบบสอบถาม

กรุณาส่งแบบสอบถามคืนที่

อาจารย์จีรีรัตน์ สกุลรัตน์
ภาควิชาวิศวกรรมโยธา
มหาวิทยาลัยสงขลานครินทร์ วิทยาเขตหาดใหญ่
ตำบลคอหงส์ อำเภอหาดใหญ่ จังหวัดสงขลา 90112

หรือ โทรสาร 074-459 396

1. รายละเอียดขององค์กร

1.1. ชื่อองค์กรของท่าน (โปรดเลือกกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม และ ระบุชื่อ)

☐ **เทศบาลนคร** ☐ **เทศบาลเมือง** ☐ **เทศบาลตำบล** ☐ **อบต** ______________________________

1.2. ขนาดพื้นที่รับผิดชอบ ____________ **ตร.กม.**

1.3. ประชากรในพื้นที่รับผิดชอบ ____________ **คน** **อัตราการเพิ่มขึ้นของประชากรในพื้นที่** ________ **%**

จำนวนประชากรแฝง ________ **% ของประชากรจริง**

2. สถานการณ์ขยะในปัจจุบัน

2.1. ปริมาณขยะที่ต้องจัดการในแต่ละวัน __________ **ตัน/วัน** (เพิ่มขึ้น หรือ ลดลง ________ % /ปี)

2.2. องค์ประกอบของขยะที่เกิดขึ้น (% โดยน้ำหนัก)

เศษอาหาร	________%	กระดาษ	________ %
พลาสติก	________%	แก้ว	________ %
เหล็ก/อลูมิเนียม	________%	อื่นๆ	________ %

3. ผู้มีส่วนร่วมในการจัดการขยะในพื้นที่รับผิดชอบขององค์กรท่าน

3.1. ผู้ใดมีส่วนเกี่ยวข้องในกิจกรรมเหล่านี้บ้าง (โปรดกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม หน้าข้อมูลตามจริง และสามารถเลือกได้มากกว่า 1 ข้อ)

3.1.1.รณรงค์ ส่งเสริม การแยกขยะ ณ ครัวเรือน	☐ ชุมชน	☐ องค์กรท้องถิ่น	☐ เอกชน	☐ไม่มี	☐ อื่นๆ
3.1.2.เก็บขนมูลฝอยจากถังรองรับขยะ	☐ ชุมชน	☐ องค์กรท้องถิ่น	☐ เอกชน	☐ไม่มี	☐ อื่นๆ
3.1.3.รวบรวมขยะเพื่อนำไปขาย	☐ ชุมชน	☐ องค์กรท้องถิ่น	☐ เอกชน	☐ไม่มี	☐ อื่นๆ
3.1.4.นำเศษอาหารไปหมักทำปุ๋ย หรือ ทำปุ๋ยน้ำชีวภาพ	☐ ชุมชน	☐ องค์กรท้องถิ่น	☐ เอกชน	☐ไม่มี	☐ อื่นๆ

3.2. จำนวนชุมชนที่มีส่วนร่วมในกิจกรรมที่เกี่ยวข้องกับขยะอย่างจริงจัง ________ **ชุมชน จากทั้งหมด** ________ **ชุมชน**

4. ประสิทธิภาพของระบบการจัดการขยะในปัจจุบันโดยองค์กรของท่าน

4.1. ระบบคัดแยกขยะ ณ แหล่งกำเนิด

มีการให้ถังสำหรับแยกขยะที่ครัวเรือนหรือไม่ ☐ มี ☐ ไม่มี

มีรถเก็บขนเฉพาะสำหรับขยะที่แยกหรือไม่ ☐ มี ☐ ไม่มี

4.2. ระบบเก็บขนและขนส่ง

จำนวนถังรองรับขยะ __________ ใบ		ขนาดถังรองรับขยะ	________ ลิตร
จำนวนรถเก็บขนขยะ __________ คัน		ขนาดรถเก็บขยะ	________ ลบ.ม.
ความถี่ในการเก็บขน __________ ครั้ง/สัปดาห์			

4.3. **ระบบบำบัดและกำจัด**

ปริมาณขยะที่แยกเพื่อนำไปขาย	________ กิโลกรัม/วัน	ความจุโรงแยก	______กก./วัน
ปริมาณขยะที่ทำปุ๋ยหมัก/ปุ๋ยน้ำ	________ กิโลกรัม/วัน	ความจุโรงปุ๋ย	______กก./วัน
ปริมาณขยะที่หมักก๊าซ	________ กิโลกรัม/วัน	ความจุโรงหมัก	______กก./วัน
ปริมาณขยะที่ทำเชื้อเพลิงอัดแท่ง	________ กิโลกรัม/วัน	ความจุโรงผลิต	______กก./วัน
ปริมาณขยะที่เข้าเตาเผา	________ ตัน/วัน	ความจุเตาเผา	______ ตัน/วัน
ปริมาณขยะที่เทกอง/ฝังกลบ	________ ตัน/วัน	พื้นที่ทิ้งขยะ	______ไร่

ขอขอบคุณในการร่วมมือตอบแบบสอบถาม

4.4. งบประมาณสำหรับการจัดการขยะทั้งหมด ______________________ **บาท/ปี**

มีการตั้งงบสำหรับซ่อมบำรุงหรือไม่ ☐ มี ☐ ไม่มี

4.5. ระบบการจัดการขยะในปัจจุบัน ประสบปัญหาใดเหล่านี้บ้าง (โปรดกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม หน้าข้อมูลตามจริง และสามารถเลือกได้มากกว่า 1 ข้อ)

☐ องค์กรท้องถิ่นไม่สามารถออกแบบระบบการจัดการขยะได้เอง

☐ องค์กรท้องถิ่นไม่สามารถเดินระบบการจัดการขยะได้เองอย่างมีประสิทธิภาพ

☐ เทคโนโลยีที่มีไม่เหมาะกับลักษณะท้องถิ่น เช่น ลักษณะขยะ ศักยภาพขององค์กรท้องถิ่น ความร่วมมือของชุมชน

☐ พื้นที่ฝังกลบกำลังจะเต็ม หรือ ขาดพื้นที่สำหรับสร้างหลุมฝังกลบ

☐ งบประมาณไม่เพียงพอต่อการสร้าง และ ซ่อม ระบบการจัดการขยะ

☐ นโยบายที่มีไม่ให้ความสำคัญต่อการแก้ปัญหาขยะ

☐ ชุมชนขาดความตระหนักถึงปัญหาขยะ

☐ ชุมชนไม่ต้องการมีส่วนร่วมในการแก้ไขปัญหาขยะ

5. ประสิทธิภาพการจัดการขยะมูลฝอยในปัจจุบันขององค์กรของท่าน

5.1. องค์กรของท่านมีข้อมูลใดบ้าง (โปรดกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม หน้าข้อมูลที่มีตามความเป็นจริง)

☐ จำนวนครัวเรือนในพื้นที่รับผิดชอบ

☐ จำนวนครัวเรือนที่สามารถเข้าถึงถังขยะที่จัดให้ได้

☐ เป้าหมายในการเก็บขน (% ของขยะที่เกิดขึ้นที่ควรถูกเก็บขน)

☐ ค่าใช้จ่ายในการเก็บขนขยะ (บาท/ตัน)

☐ ปริมาณขยะที่ต้องเก็บในแต่ละเส้นทางของรถเก็บขน (ตัน)

☐ จำนวนจุดเก็บขนของรถแต่ละคัน

☐ ขนาดของรถเก็บขนขยะแต่ละคัน (ลบ.ม.)

☐ เวลาที่ใช้ในการเก็บขนของรถแต่ละคัน (ชม./เที่ยว)

☐ ระยะทางเก็บขนของรถเก็บขนขยะแต่ละคัน (กิโลเมตร)

☐ เส้นทางเก็บขนของรถแต่ละคัน

☐ จำนวนเที่ยวในการเก็บขนขยะของรถแต่ละคัน (เที่ยว/คัน)

☐ จำนวนชั่วโมงทำงานที่ใช้จริงของรถเก็บขนแต่ละคัน (ชม./วัน)

☐ เป้าหมายในการแยกขยะไปขาย (% ของขยะที่ควรนำไปขาย)

☐ ปริมาณขยะแต่ละชนิดที่คัดแยกได้ (กก.)

☐ ค่าใช้จ่ายทั้งหมดในการคัดแยกขยะ (บาท)

☐ รายได้ทั้งหมดที่ได้จากขยะที่คัดแยกได้ (บาท)

☐ องค์ประกอบทางเคมีของขยะที่นำมาทำปุ๋ย

☐ ความจุของสถานที่ทำปุ๋ย (กก./วัน)

☐ ปริมาณปุ๋ยที่ผลิตได้ในแต่ละวัน (กก./วัน)

☐ คุณภาพของปุ๋ยที่ผลิตได้

☐ ปริมาณของเสียที่เหลือจากสถานที่หมักทำปุ๋ย (กก./วัน)

☐ ปริมาณของเสียที่นำไปฝังกลบ (กก.)

☐ ค่าใช้จ่ายทั้งหมดในการหมักทำปุ๋ย (บาท)

☐ รายได้จากการจำหน่ายปุ๋ยที่ผลิตได้ (บาท)

☐ อายุการใช้งานทั้งหมดของหลุมฝังกลบ (ปี)

☐ อายุการใช้งานที่เหลือของหลุมฝังกลบ (ปี)

☐ ปริมาณขยะทั้งหมดที่เข้าหลุมฝังกลบแต่ละวัน (ตัน/วัน)

☐ ปริมาณน้ำชะขยะที่เกิดขึ้นจากหลุมฝังกลบ (ลบ.ม.)

☐ อัตราการเกิดขยะ (กก./คน/วัน)

☐ อัตราการเพิ่มของขยะ (%/ปี)

☐ องค์ประกอบทางกายภาพของขยะที่เกิดขึ้น

☐ องค์ประกอบทางเคมีของขยะที่เกิดขึ้น

5.1.1. ข้อมูลเหล่านี้ถูกจัดเก็บไว้ในที่เดียวกันหรือไม่ ☐ ใช่ ☐ ไม่ใช่

5.1.2. ข้อมูลที่มีนี้สามารถเรียกใช้ได้อย่างสะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

5.1.3. ข้อมูลเหล่านี้ถูกจัดเก็บอยู่ในรูปแบบใดบ้าง ☐ เอกสาร ☐ แฟ้มข้อมูลในคอมพิวเตอร์

ขอขอบคุณในการร่วมมือตอบแบบสอบถาม

5.2. ท่านมีรายละเอียดใดบ้างก่อนตัดสินใจเลือกวิธีการจัดการขยะที่ต้องการ (ตั้งแต่ การลด เก็บขน บำบัด และฝังกลบ)

☐ ประสิทธิภาพของระบบการจัดการขยะในปัจจุบัน ☐ ประสิทธิภาพของวิธีการใหม่ที่ต้องการนำมาใช้

5.3. หลักเกณฑ์ใดบ้างที่ใช้พิจารณาเลือกระบบการจัดการขยะที่เหมาะสม

☐ ประสิทธิภาพ ☐ เศรษฐศาสตร์ และการเงิน ☐ ผลกระทบทางสิ่งแวดล้อม ☐ ผลกระทบทางสังคม

5.4. ท่านมีโปรแกรมคอมพิวเตอร์ ช่วยในขั้นตอนใดบ้าง

☐ วิเคราะห์ปัญหาของระบบจัดการขยะในปัจจุบัน ☐ ออกแบบทางเลือกของแผนกลยุทธ์เพื่อแก้ปัญหาขยะที่เกิดขึ้น

☐ วิเคราะห์ประสิทธิภาพของแต่ละทางเลือก ☐ เลือกระบบการจัดการขยะที่เหมาะสมที่สุด ☐ ไม่มี

5.5. มีการประชุมในส่วนงานของท่านก่อนการตัดสินใจเลือกระบบการจัดการขยะที่เหมาะสมหรือไม่ ☐ มี ☐ ไม่มี

5.6. มีการสอบถามความคิดเห็นของประชาชนในพื้นที่ก่อนการตัดสินใจเลือกระบบหรือไม่ ☐ มี ☐ ไม่มี

5.7. ประชาชนในพื้นที่มีส่วนร่วมในการออกแบบระบบการจัดการขยะหรือไม่ ☐ มี ☐ ไม่มี

5.8. องค์กรเอกชนมีส่วนร่วมในการออกแบบและเดินระบบการจัดการขยะหรือไม่ ☐ มี ☐ ไม่มี

5.9. องค์กรท่านมีแผนประเภทใดบ้างในการจัดการขยะในพื้นที่

☐ ไม่มี โปรดข้ามไปตอบคำถามที่ 5.10

☐ มี ☐ แผนระยะยาว (ระยะ 7 – 20 ปี) โปรดตอบคำถามที่ 5.9.1.1 – 5.9.1.4

☐ แผนระยะกลาง หรือ สั้น (ระยะ 1 – 7 ปี) โปรดตอบคำถามที่ 5.9.2.1 – 5.9.2.4

☐ แผนปฏิบัติการประจำวัน โปรดตอบคำถามที่ 5.9.3.1 – 5.9.3.4

5.9.1.1. ผู้ใดมีส่วนร่วมในการเตรียมแผนระยะยาว (7 – 20 ปี) ☐ เจ้าหน้าที่ในองค์กร ☐ หน่วยงานภายนอก ☐ ชุมชน

5.9.1.2. แผนระยะยาวนี้นำเสนอประเด็นใดบ้าง

☐ สภาพทั่วไปของพื้นที่รับผิดชอบ (เช่น โครงสร้างเศรษฐกิจและสังคม, ประชากร, ปริมาณขยะ)

☐ เป้าหมายหรือหลักการของระบบการจัดการขยะที่ออกแบบ

☐ องค์ประกอบของระบบการจัดการขยะทั้งหมด ตั้งแต่ การลด เก็บขน บำบัด และฝังกลบ

☐ รายละเอียดของแต่ละขั้นตอนของระบบการจัดการขยะ

☐ แผนการดำเนินการสร้างระบบการจัดการขยะ

☐ เทคโนโลยีที่ใช้ในแต่ละขั้นตอนของระบบการจัดการขยะ

5.9.1.3. แผนระยะยาวนี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ **สะดวก** ☐ **ไม่สะดวก**

5.9.1.4. แผนระยะยาวนี้ให้ข้อมูลที่เป็นประโยชน์ต่อการจัดการขยะในปัจจุบันหรือไม่

☐ ใช่ ☐ ไม่ใช่, โปรดอธิบาย ______________________________

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ขอขอบคุณในการร่วมมือตอบแบบสอบถาม

5.9.2.1. ผู้ใดมีส่วนร่วมในการเตรียมแผนระยะกลาง (1 – 7 ปี) ☐ เจ้าหน้าที่ในองค์กร ☐ หน่วยงานภายนอก ☐ ชุมชน

5.9.2.2. แผนระยะกลางนี้นำเสนอประเด็นใดบ้าง

☐ เป้าหมายของโครงการ ☐ ระยะเวลาโครงการ
☐ วิธีการดำเนินการ ☐ อุปกรณ์ เครื่องมือที่ต้องการสำหรับโครงการ
☐ บุคลากรที่ต้องการ ☐ งบประมาณที่ต้องการ
☐ ตัวชี้วัดประสิทธิภาพของโครงการ

5.9.2.3. แผนระยะกลางนี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ **สะดวก** ☐ **ไม่สะดวก**

5.9.2.4. แผนระยะกลางนี้ให้ข้อมูลที่เป็นประโยชน์ต่อการจัดการขยะในปัจจุบันหรือไม่

☐ ใช่ ☐ ไม่ใช่, โปรดอธิบาย ____

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5.9.3.1. ผู้ใดมีส่วนร่วมในการเตรียมแผนปฏิบัติการประจำวัน ☐ เจ้าหน้าที่ในองค์กร ☐ หน่วยงานภายนอก ☐ ชุมชน

5.9.3.2. แผนปฏิบัติการประจำวันนี้นำเสนอประเด็นใดบ้าง

☐ รายละเอียดของงานที่ต้องปฏิบัติในแต่ละวัน ☐ บุคลากรในการปฏิบัติแต่ละงาน
☐ ตารางเวลาการปฏิบัติงาน ☐ อุปกรณ์ในการปฏิบัติแต่ละงาน

5.9.3.3. แผนปฏิบัติการนี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ **สะดวก** ☐ **ไม่สะดวก**

5.9.3.4. แผนปฏิบัติการนี้เสนอข้อมูลที่เป็นประโยชน์ต่อการจัดการขยะในปัจจุบันหรือไม่

☐ ใช่ ☐ ไม่ใช่, โปรดอธิบาย ____

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5.10. องค์กรท่านมีเอกสารแสดงรายละเอียดใดบ้าง (โปรดกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม หน้าข้อมูลที่มี ตามจริง)

☐ ขั้นตอนการวางแผน/ออกแบบระบบ ☐ วิธีการจัดการระบบการวางแผน
☐ วิธีการจัดการข้อมูลสำหรับวางแผน ☐ รายชื่อผู้เกี่ยวข้องในงานแต่ละด้านของการเตรียมแผน
☐ วิธีการเลือกระบบการจัดการขยะที่เหมาะสม ☐ ตารางเวลาในการเตรียมแผนการจัดการ

5.10.1. เอกสารเหล่านี้สามารถนำมาใช้ได้สะดวกโดยเจ้าหน้าที่ที่เกี่ยวข้องหรือไม่ ☐ สะดวก ☐ ไม่สะดวก

5.11. องค์กรท่านมีค่าใช้จ่ายเฉพาะสำหรับกิจกรรมใดบ้าง

☐ การทำแผนสำหรับการจัดการขยะ ☐ การอบรมบุคลากรที่เกี่ยวข้องในเรื่องออกแบบระบบการจัดการขยะ
☐ จัดซื้อเครื่องมือ อุปกรณ์ ที่เกี่ยวข้องกับการวางแผนระบบการจัดการขยะ

5.12. ท่านมีอุปกรณ์ใดบ้างเพื่อช่วยออกแบบระบบจัดการขยะ ☐ **เครื่องคอมพิวเตอร์** ☐ **ซอฟแวร์/โปรแกรม** ☐ **คู่มือ**

ขอขอบคุณในการร่วมมือตอบแบบสอบถาม

5.13. จำนวน<u>เจ้าหน้าที่</u>ที่เกี่ยวข้องกับการเตรียมแผนและออกแบบระบบการจัดการมูลฝอย _________ คน

5.13.1. มีการจัดอบรมเพื่อเพิ่มความรู้ด้านการวางแผนให้กับเจ้าหน้าที่ที่เกี่ยวข้องเหล่านี้หรือไม่ ☐ มี ☐ ไม่มี

5.13.2. มีกลไกในการส่งเสริมความตั้งใจในการทำงานของเจ้าหน้าที่ที่เกี่ยวข้องเหล่านี้หรือไม่ ☐ มี ☐ ไม่มี

5.13.3. มีการแจงรายละเอียดของงานต่อเจ้าหน้าที่ที่เกี่ยวข้องเหล่านี้ก่อนการทำงานหรือไม่ ☐ มี ☐ ไม่มี

5.14. จำนวนเจ้าหน้าที่ทั้งหมดในองค์กรของท่าน ________ คน (ไม่รวมพนักงานเก็บขนและกำจัดขยะ)

5.15. โครงสร้างบริหารองค์กรในปัจจุบันให้ความสะดวกในการออกแบบและเดินระบบจัดการขยะหรือไม่ ☐ ใช่ ☐ ไม่ใช่

5.16. ขณะนี้มีการร้องเรียนเกี่ยวกับปัญหาขยะหรือไม่ ☐ มี ☐ ไม่มี

5.17. องค์กรของท่านมีแนวคิดที่จะนำวิธีการใหม่ๆ มาใช้จัดการขยะในพื้นที่รับผิดชอบ หรือไม่ ☐ มี ☐ ไม่มี

5.18. องค์กรของท่านมีหลุมฝังกลบมูลฝอยอย่างถูกสุขลักษณะของ <u>ตนเอง</u> หรือไม่ ☐ มี ☐ ไม่มี

5.19. ลักษณะของพื้นที่ทิ้งมูลฝอยเป็นอย่างไร

☐ ไม่อยู่ในพื้นที่ลุ่มน้ำชั้นที่ 1 และ 2

☐ ตั้งห่างจากเขตโบราณสถานมากกว่า 1 กิโลเมตร

☐ ตั้งห่างจากเขตชุมชนหลักมากกว่า 2 กิโลเมตร

☐ ตั้งห่างจากแหล่งน้ำผลิตน้ำประปามากกว่า 500 เมตร

☐ ตั้งห่างจากแหล่งน้ำสาธารณะมากกว่า 300 เมตร

☐ ตั้งห่างจากแนวเขตสนามบินมากกว่า 5 กิโลเมตร

☐ มีชั้นดินเหนียวและแผ่นพลาสติกกันซึมด้านล่าง

☐ มีระบบรวบรวมน้ำชะมูลฝอย

☐ มีระบบรวบรวมก๊าซ

☐ มีการปิดทับหน้าทุกวัน

☐ มีระบบตรวจสอบคุณภาพน้ำใต้ดิน

5.20. องค์กรของท่านใช้หลุมฝังกลบมูลฝอยอย่างถูกสุขลักษณะของ <u>องค์กรอื่น</u> หรือไม่ ☐ ใช่ ☐ ไม่ใช่

5.21. <u>องค์กรอื่น</u> ใช้หลุมฝังกลบขององค์กรท่าน หรือไม่ ☐ ไม่ใช้ ☐ ใช้ ปริมาณขยะจากนอกพื้นที่ ________ ตัน/วัน

5.22. ท่านคิดว่าระบบการจัดการขยะขององค์กรท่านในปัจจุบันมีปัญหาในลักษณะใดบ้าง (โปรดกาเครื่องหมาย ✓ ลงในช่องสี่เหลี่ยม หน้าข้อมูลตามจริง ***<u>สามารถเลือกได้มากกว่า 1 ข้อ</u>***)

☐ ไม่มีระบบในพื้นที่

☐ มีระบบ แต่ไม่เพียงพอ (จำนวนถังขยะ รถเก็บขนขยะ ไม่เพียงพอต่อปริมาณขยะที่เกิดขึ้น)

☐ มีระบบ แต่ไม่สม่ำเสมอ (ไม่สามารถเก็บขนได้ตามวันและเวลาที่กำหนด)

☐ มีระบบ แต่ไม่ถูกสุขลักษณะ (มีปัญหาสิ่งแวดล้อมจากขยะด้านอื่นๆ เช่น น้ำเสีย อากาศเสีย)

☐ มีระบบ แต่ไม่ยั่งยืน (สามารถรองรับขยะที่เกิดขึ้นได้อีกไม่เกิน 10 ปี)

☐ มีระบบ เพียงพอ สม่ำเสมอ ถูกสุขลักษณะ และยั่งยืน (สามารถรองรับขยะที่เกิดขึ้นได้นานกว่า 20 ปี)

ขอขอบคุณในการร่วมมือตอบแบบสอบถาม

APPENDIX B

Table B-1: Sustainability score and performance level of studied Nakhon and Muang municipalities

Local Authority	Engineering System (0.5)						Local authority capability (0.3)				Public (0.1)		Collaboration (0.1)				Sustainability Score	Performance Level
	E1 (0.1)	E2 (0.1)	E3 (0.1)	E4 (0.3)	E5 (0.3)	E6 (0.1)	L1 (0.35)	L2 (0.15)	L3 (0.15)	L4 (0.35)	P1 (0.5)	P2 (0.5)	C1 (0.25)	C2 (0.25)	C3 (0.25)	C4 (0.25)		
NM1	0.10	0.10	0.00	0.06	0.18	0.07	0.16	0.00	0.03	0.14	0.50	0.13	0.25	0.08	0.06	0.19	0.47	3
NM2	0.07	0.10	0.00	0.00	0.12	0.03	0.20	0.00	0.03	0.28	0.25	0.25	0.25	0.17	0.00	0.19	0.43	3
NM3	0.04	0.10	0.00	0.30	0.18	0.06	0.20	0.15	0.00	0.14	0.25	0.13	0.25	0.17	0.00	0.25	0.59	3
NM4	0.10	0.10	0.07	0.30	0.24	0.08	0.35	0.15	0.05	0.35	0.50	0.50	0.25	0.25	0.25	0.25	0.91	5
NM5	0.06	0.04	0.00	0.30	0.18	0.03	0.15	0.15	0.04	0.14	0.25	0.13	0.00	0.00	0.00	0.19	0.51	3
NM6	0.09	0.10	0.00	0.13	0.18	0.06	0.20	0.08	0.05	0.28	0.50	0.38	0.25	0.08	0.13	0.25	0.62	4
MM1	0.07	0.10	0.00	0.24	0.12	0.04	0.21	0.08	0.12	0.21	0.50	0.13	0.00	0.17	0.00	0.19	0.57	3
MM2	0.10	0.10	0.00	0.30	0.18	0.06	0.16	0.15	0.03	0.07	0.00	0.13	0.00	0.08	0.00	0.13	0.52	3
MM3	0.10	0.10	0.00	0.00	0.18	0.06	0.20	0.08	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.06	0.33	2
MM4	0.10	0.10	0.00	0.30	0.18	0.06	0.20	0.15	0.03	0.14	0.25	0.25	0.25	0.17	0.00	0.06	0.62	4
MM5	0.10	0.10	0.00	0.19	0.18	0.06	0.00	0.00	0.03	0.00	0.25	0.13	0.00	0.00	0.00	0.19	0.38	2
MM6	0.10	0.10	0.00	0.30	0.00	0.02	0.35	0.05	0.01	0.07	0.00	0.25	0.00	0.17	0.00	0.19	0.46	3
MM7	0.10	0.10	0.00	0.00	0.18	0.06	0.20	0.15	0.01	0.14	0.25	0.00	0.25	0.08	0.06	0.06	0.44	3
MM8	0.10	0.10	0.00	0.02	0.00	0.02	0.15	0.00	0.00	0.07	0.00	0.13	0.00	0.00	0.06	0.06	0.21	1

Table B-2: Sustainability score and performance level of studied Tambon municipalities

Local Authority	**Engineering System (0.5)**						**Local authority capability (0.3)**				**Public (0.1)**		**Collaboration (0.1)**				**Sustainability Score**	**Performance Level**
	E1 (0.1)	E2 (0.1)	E3 (0.1)	E4 (0.3)	E5 (0.3)	E6 (0.1)	L1 (0.35)	L2 (0.15)	L3 (0.15)	L4 (0.35)	P1 (0.5)	P2 (0.5)	C1 (0.25)	C2 (0.25)	C3 (0.25)	C4 (0.25)		
TM1	0.10	0.03	0.00	0.30	0.00	0.02	0.05	0.00	0.03	0.14	0.00	0.13	0.25	0.08	0.00	0.06	0.34	2
TM2	0.10	0.10	0.00	0.30	0.24	0.07	0.21	0.15	0.12	0.14	0.00	0.13	0.25	0.08	0.00	0.00	0.64	4
TM3	0.02	0.10	0.00	0.10	0.18	0.04	0.11	0.00	0.02	0.07	0.25	0.25	0.25	0.00	0.13	0.00	0.37	2
TM4	0.10	0.10	0.00	0.29	0.18	0.06	0.16	0.15	0.03	0.14	0.00	0.25	0.25	0.00	0.06	0.06	0.57	3
TM5	0.10	0.08	0.00	0.22	0.18	0.04	0.20	0.15	0.11	0.14	0.25	0.13	0.25	0.17	0.06	0.00	0.58	3
TM6	0.10	0.10	0.00	0.30	0.18	0.07	0.15	0.00	0.03	0.07	0.00	0.00	0.25	0.00	0.00	0.19	0.49	3
TM7	0.03	0.10	0.00	0.30	0.00	0.01	0.15	0.00	0.01	0.07	0.25	0.13	0.00	0.00	0.00	0.06	0.33	2
TM8	0.10	0.08	0.00	0.00	0.00	0.01	0.15	0.15	0.03	0.07	0.00	0.00	0.25	0.00	0.00	0.00	0.24	2
TM9	0.10	0.06	0.00	0.30	0.00	0.02	0.20	0.08	0.01	0.21	0.50	0.25	0.00	0.17	0.00	0.13	0.49	3

Table B-3: Sustainability score and performance level of studied Tambon Administrative Organisation

Local Authority	Engineering System (0.5)						Local authority capability (0.3)				Public (0.1)		Collaboration (0.1)				Sustainability Score	Performance Level
	E1 (0.1)	E2 (0.1)	E3 (0.1)	E4 (0.3)	E5 (0.3)	E6 (0.1)	L1 (0.35)	L2 (0.15)	L3 (0.15)	L4 (0.35)	P1 (0.5)	P2 (0.5)	C1 (0.25)	C2 (0.25)	C3 (0.25)	C4 (0.25)		
TAO1	0.10	0.10	0.00	0.30	0.18	0.07	0.20	0.08	0.06	0.14	0.25	0.25	0.25	0.17	0.13	0.06	0.63	4
TAO2	0.10	0.08	0.00	0.30	0.00	0.02	0.15	0.00	0.07	0.00	0.00	0.00	0.25	0.08	0.00	0.06	0.36	2
TAO3	0.01	0.10	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.07	0.00	0.25	0.25	0.00	0.00	0.06	0.15	1
TAO4	0.10	0.07	0.00	0.30	0.00	0.02	0.00	0.00	0.14	0.00	0.00	0.13	0.00	0.00	0.00	0.25	0.32	2
TAO5	0.10	0.08	0.00	0.30	0.00	0.01	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.31	2
TAO6	0.09	0.10	0.00	0.30	0.18	0.06	0.21	0.15	0.08	0.14	0.25	0.50	0.25	0.17	0.19	0.19	0.69	4
TAO7	0.00	0.00	0.00	0.00	0.00	0.01	0.20	0.00	0.01	0.00	0.00	0.13	0.00	0.08	0.00	0.13	0.10	0
TAO8	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.25	0.13	0.25	0.00	0.06	0.19	0.09	0
TAO9	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.06	0.04	0
TAO10	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.13	0.25	0.00	0.00	0.13	0.06	0
TAO11	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0
TAO12	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0
TAO13	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0
TAO14	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0
TAO15	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0
TAO16	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01	0
TAO17	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00	0.13	0.25	0.00	0.00	0.06	0.06	0

Table B-3: Sustainability score and performance level of studied Tambon Administrative Organisation (con't)

Local Authority	Engineering System (0.5)						Local authority capability (0.3)				Public (0.1)		Collaboration (0.1)				Sustainability Score	Performance Level
	E1 (0.1)	E2 (0.1)	E3 (0.1)	E4 (0.3)	E5 (0.3)	E6 (0.1)	L1 (0.35)	L2 (0.15)	L3 (0.15)	L4 (0.35)	P1 (0.5)	P2 (0.5)	C1 (0.25)	C2 (0.25)	C3 (0.25)	C4 (0.25)		
TAO18	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.06	0.00	0
TAO19	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.25	0.00	0.00	0.06	0.25	0
TAO20	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0
TAO21	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.06	0.00	0
TAO22	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.25	0.13	0.00	0.08	0.00	0.06	0.00	0
TAO23	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0
TAO24	0.02	0.10	0.00	0.30	0.00	0.01	0.11	0.00	0.00	0.14	0.00	0.00	0.25	0.08	0.00	0.00	0.25	2
TAO25	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0
TAO26	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.07	0.00	0.00	0.25	0.00	0.00	0.06	0.25	0
TAO27	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0

APPENDIX C

Implementation Capability						
Name of Local Authority			**Population growth rate calculation**			
Responsible Area	21	Sq.Km.		Initial	Last	
Registered Population	200,000	cap	Year	2546	2547	
Population Growth Rate	0.62	%	Population	157,206	157,773	cap
Non-Registered Population	5.00	%	Growth rate		0.36	%
Number of communities	20					
Quantity of generated waste before separation	199	tons/day	**Waste generation growth rate calculation**			
Generation Growth Rate	0.95	%		Initial	Last	
Waste density	250	kg/m3	Year	2004	2008	
			Waste generation	1.04	1.08	kg/cap/day
Waste composition **Food/Organics**	48.2	%	Growth rate		0.96	%
Papers	6.1	%				
Plastics	14.6	%				
Glasses	8.2	%				
Metal/Aluminium	1.0	%				
					No. of Communities	
Public related Activities (0,1)	-	Source separation campaign and promotion			-	
	-	Waste collection			-	
	-	Waste separation for recycling			-	
	1	Waste composting at source			-	
People willing to participate in the program	50	% Average	* based on the survey			
People willing to pay for the services	78	% Average	* based on the survey			
People that actually participate in the programs	20	% Average	* based on the survey			
Private sector related Activities (0,1)	-	Source separation campaign and promotion				
	-	Waste collection				
	-	Waste separation for recycling				
	-	Waste composting at source				
Local authority related Activities (0,1)	1	Source separation campaign and promotion			-	
	1	Waste collection				
	1	Waste separation for recycling				
	1	Waste composting at source				

Figure C-1: Input Worksheet 1

Implementation Capability								
Source Separation System	1	Container for separated waste is provided						
	1	Truck for separated waste is available						
Quantity of organics separated at source	31	tons/day						
Quantity of recyclables separated at source	-	tons/day						
Storage System	**Size (litres)**	**Number**						
Waste container	120	2,500						
Collection System	**Size (m3)**	**Number**	**No. of trip /day**					
Waste collection truck	21	17	2			**Collection Frequency**	7	times/week
	11	16	2					
	7.5	5	2			**Waste collected by private company**	-	tons/day
	7	16	2					
	4	2	2			**Waste collected local authorities**	-	tons/day
	21	5	2					
	3	6	2					
Treatment System								
Waste going to Composting facility	2,000	tons/day	Capacity of Composting facility		5	tons/day		
Compost product	800	tons/day	Available wastewater treatment (0		1			
Waste going to EM liquid facility	2,000	tons/day	Capacity of EM liquid facility		5	tons/day		
Residual sludge		tons/day						
Waste going to Anaerobic digester	-	tons/day	Capacity of Anaerobic digester		-	tons/day		
Residual sludge	-	tons/day						
Waste going to Material Recovery Facility	5,000	tons/day	Capacity of Material Recovery Faci		10	tons/day		
Recovered materials		tons/day						
Waste going to Incinerator	-	tons/day	Capacity of Incinerator		-	tons/day		
Residual ash		tons/day						

Figure C-1: Input Worksheet 1 (con't)

Implementation Capability					
Disposal System					
Waste going to Open dump site	-	tons/day	Land area size	-	rai
Inside waste going to Sanitary landfill	161	tons/day	Available land area size	10	rai
Outside waste going to Sanitary landfill	-	tons/day			
Landfill pollution control measures	1	Bottom liner is installed			
	-	Leachate collection system is installed			
	-	Landfill gas collection system is installed			
	-	Daily cover is utilised			
	1	Groundwater monitoring well			
Total budget for MSW management	72,000,000	Baht/year			
Available budget for maintenance	1				
Actual operating cost	18,015,600	Baht/year			
Services Fee collection	6,760,390	Baht/year			
Current barriers to MSW management system	-	local authorities that are unable to plan appropriate management system			
	-	local authorities that are unable to operate according to the plan			
	-	Implemented technologies are not suitable to local content			
	1	Available budget is not sufficient for constructing and operating			
	-	MSW problem is not priority			
	-	public is not aware of MSW problem			
	-	public is not willing to participate in the system			
	-	appropriate land area is not available for disposal			

Figure C-1: Input Worksheet 1(con't)

Planning Capability			
Local authority related Activities		Waste separation for recycling	
		Waste composting at source	
Information Management system			
Available data for planning		Storage and Collection (12)	
		Recovery for recycling (4)	
		Composting (8)	
		Disposal (4)	
		Waste (4)	
Available data is centrally stored			
Available data is conveniently accessed			
Format of Available data		Paper/ Document	
		Computer Files	**IMS Score**
Decision Support System			
Available information for planning		Performance of Existing management system	
		Performance of Proposed management system	
System selection criteria		Efficiency	
		Economics	
		Environmental impact	
		Social impact	
Decision making process		Formal meeting	
		Public hearing	
		Public is involved in the process	
		Private sector is involved in the process	**DSS Score**

Figure C-2: Input Worksheet 2

Planning Capability						
Plan Management System						
Stakeholders in Strategy Preparation		Local authority				
		Private sector				
		Public				
Strategy Content		Background of the responsible area				
		Objective or principle of the entire management system				
		All components of the management system				
		Detail of each component				
		Schedule for implementing new facilities				
		Technology of each component				
Available strategy is conveniently accessed						
Available strategy is useful for implementation					S Score	
Plan Management System						
Stakeholders in Project Plan Preparation		Local authority				
		Private sector				
		Public				
Project Plan Content		Target of Project				
		Activities to achieve the target				
		Human resources required				
		Performance Indicators of each process				
		Project Time frame				
		Equipment/ Facilities required				
		Budget required				
Available project is conveniently accessed						
Available project is useful for implementation					P Score	
Stakeholders in Project Plan Preparation		Local authority				
		Private sector				
		Public				
Operating Plan Content		Tasks for each process				
		Schedule of each task				
		Crews for each task				
		Equipment for each task				
Available operating plan is conveniently accessed						
Available operating plan is useful for implementation					O Score	

Figure C-2: Input Worksheet 2 (con’t)

Planning Capability					
Planning Management System					
Availability of Planning related Document		Planning procedure			
		Information Management System			
		Decision Support System			
		Planning Management System			
		List of Planning Activities and Corresponding Staff			
		Planning Schedule			
These documents are conveniently accessed				**PMS Score**	
Planning Support System					
Available Budget		Running the planning activities			
		Training corresponding staff			
		Acquiring planning facilities			
Available planning facilities		Computer			
		Software			
		Planning manual			
Type of supporting tool		Diagnose problem			
		Formulate choices of strategies			
		Evaluate each choice of strategies			
		Select the best choice			
Available improvement measures		Training program			
		Encourage enthusiasm and commitment mechanism			
		Clear instruction provision		**PSS Score**	
Planning Staff					
Number of Planning staff				**PS Score**	
Administrative System					
Administrative structure supports planning process				**AS Score**	
Waste is going to your own sanitary landfill	1				
There are serious complaints on MSW	1				
New MSW management activities are planned	1				
Plan Score				**No. of Plans**	
Basic Score				**Possible No. of Plans**	
Planning capability					
Capability Utilisation					

Figure C-2: Input Worksheet 2 (con't)

VITAE

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