Modeling a hierarchical structure of municipal solid waste management using interpretive structural modeling

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Abstract: - Municipal solid waste management (MSWM) is the fundamental environmental management in urban area, the characteristic of uncontrolled burning of wastes and improper incineration contributes significantly to urban air pollution needed for citizen life. This study proposed 18 criteria on Taipei metropolitan using interpretive structural modeling (ISM) with interrelationships among the criteria, influencing MSWM activities which have been derived. However, there are few studies proposed this analytical technique in building the hierarchical structure and result in driving and dependence power, none of them are proposed in environmental management. The ISM provides a means by which order can be imposed on the complicated interrelations of criteria. The proposed criteria categorizes according to driving and dependence power into a hierarchical structure model. The insight from model would help the management in strategic planning for improving MSWM activities. The results and concluding remarks are discussed.

Key-Words: - municipal solid waste management; interpretive structural modeling; hierarchical structure

1 Introduction

With different social and economic realities, consumption patterns, and technological development levels, municipalities in different countries have adopted varying approaches. Taipei metropolitan is the Taiwan's economic gateway to the world. Taipei serves as the country's major commercial, financial and educational center and the heart of the country's national government where the major administrative offices are located. The consumption and production behavior of its millions of residents greatly threatens the quality of its environment and the integrity of its natural resources. The municipal solid waste (MSW) is one of the waste products generated from daily life and various activities. It increases with the growth of personal income and population. The municipal solid waste management (MSWM) studies are important for several reasons, such as the need to estimate material recovery potential, to identify sources of component generation, to facilitate the design of processing equipment, and to maintain compliance with national laws (Gidarakos et al., 2006; Rotich et al., 2006; Geng et al., 2010; Tseng et al., 2008a;b). In order to reduce the demand for landfill space, incinerators have been built to reduce the final disposal volume of MSW. The amount of MSW generated in Taipei metropolitan area in 2009 was 3.6 million tons. Hence, the proper management is important to control the populations due to improper management activities can increase threaten public health, contaminate ground and surface water, and create greenhouse gas emissions.

Hence, the improper activities cause all types of pollution: air, soil, and water. Indiscriminate dumping of wastes contaminates surface and ground water supplies, due to increasing environmental pressure and decreasing landfill capacity, prevention of MSW and promoting reuse, recycling and recovery are becoming more popular (Buttol et al., 2007; Tseng, 2010). In urban areas, solid waste clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Uncontrolled burning of wastes and improper incineration contributes significantly to urban air pollution. MSW is one of major theme related to pollutions. The living consumption causes the generation of a lot of solid wastes that create

environmental impact and health risks. If waste collection is not managed carefully, it could carry out serious health and environmental problems. More importantly, the effective MSW largely begins with a proper management. To implement the MSWM successfully, there is a critical issue of how can better structure a hierarchical model for the multi- criteria basis evaluation. In past literatures, there is none study proposed a rigor method to compose a hierarchical structure of MSWM.
Moreover, the evaluation usually involves qualitative judgment. In particular, MSWM is a strategic issue, which is restricted by resource needs, realistic support, time requirements, conformity with expected outcomes etc (Vego et al. 2007; Wu and Lee, 2007; Huang et al., 2008; Khan and Faisal, 2007; Tseng, 2009). In this sense, the treatment of MSWM is required to handle several complex interdependence criteria in a better sensible and logical manner. Aforementioned, this study proposes applied interpretive structural modeling (ISM) to evaluate the subjective judgment and interdependence relations among the criteria into hierarchical structure. However, since there is interdependence relations existed among the criteria. The traditional structural equation modeling approach is no longer suited to evaluate the interdependence relations among criteria and model into a hierarchical structural framework. Therefore, a typical study to understand the hierarchical interdependence relations and framework is through the use of the ISM is an interactive learning process in which a set of different and directly related criteria is structured into a comprehensive systemic model (Warfield, 1974). ISM is a suitable modeling technique for analyzing the influence of one criterion on other criteria. The model so formed portrays the structure of a complex issue or problem, a field of study, in a carefully designed pattern implying graphics as well as words. ISM helps to impose order and direction on the complexity of relationships and composes into of a system of hierarchical structural framework.

This study attempts to develop a hierarchical framework that is sufficiently general and can be applied in this approach. To determine the hierarchical structure and performance of criteria, the evaluation is multiple and frequently structured into multi-level hierarchies. ISM is a modeling technique as the specific relationships and overall structure is portrayed in a digraph model. This study presents a hierarchical structure that is sufficiently general and it can be applied under various study settings. This approach intends to systematically address the actions that have already been taken, and also to describe the measures that are important for the development of MSWM. Consequently, the resolving problem is fundamentally important to both researchers and practitioners. The unique points of this study involved qualitative measures into interrelationships for analysis in dependence and driving powers. Thereafter, uses ISM technique to draw and identifies the relative dependence and driving powers associated with the degree of dependence and driving powers in quadrants. The quadrants are autonomous, dependent, linkage and independent criteria clusters (Agarwal et al., 2007). The rest of this paper is organized as follows. In Section 2, literatures relevant to the topic are reviewed. In Section 3 is the hierarchical structure of MSWM. Section 4, evaluation methods are presented. In Section 5, an empirical study is presented. Finally, according to the managerial implications of this study, concluding remarks are addressed in Section 6.

2 Literature review

The section aims to identify the theoretical composition of MSWM. The literatures are described in multi-criteria evaluation, the management approach should guide as a strategic, decision-making perspective and identify status quo for the necessary improvement.

2.1 Municipal solid waste management

After the 1990s, as MSW policies became more complicated, the factors to be considered also increased; hence, several MSWM models with deeper analysis emerged. Hokkanen and Salminen (1997) applied the decision making method to select a MSWM system in Finland, with eight criteria; namely: cost per ton, technical reliability, global effects, local and regional health effects, acidic releases, surface water dispersed releases, number of employees, and amount of recovered waste. Twenty-two alternatives under either decentralized or centralized management systems were examined, with various treatment methods such as composting, Refuse-derived fuel combustion, and landfill. However, the factors considered in MSWM models tend to be mainly economic (e.g., system cost and system benefit), environmental (air emission, water pollution) and technological (the maturity of the technology) (Su et al., 2007; Vego et al., 2008; Tseng et al. 2008a; Tseng 2009). Moreover, Wilson et al. (2001) interviewed eleven different leading edge European MSW programs in nine countries, proposed that ‘‘including different public groups in the process from the very beginning can help avoid the high levels of controversy and public opposition that have surrounded many MSW projects’’. Morrissey and Browne (2004) propose that a sustainable MSWM model should not be only environmentally effective and economically affordable but also socially acceptable.

Su et al. (2007) studies many modern decision making support systems which partially consider social factor analysis in addition to expenses and benefits, environmental effects, technical issues, and management aspects. A study in Taiwan’s major MSW policies in the past 10 years discovered that there is still a great deal of uncertainty associated with policy implementation, even when the effects of factors related to environmental, economic, social, technological, and management aspects have been considered. Their concepts underlying sustainable MSWM models can be divided into two categories; this same clustering was also supported by various researchers. The first category incorporates social factors into decision making methods (Chung and Lo, 2003, Cavallaro and Ciraolo, 2005, Hernandez and Martin- Cejas, 2005), whereas the other model incorporates public participation into the decision making process (Ananda and Herath, 2003, Skordilis, 2004). In conclusion, MSWM proposes generally in four directions human development, social, economical and sustainable development criteria to be evaluated. These proposed criteria are used extensively in Chung and Lo (2003), Hernandez and Martin-Cejas (2005), Skordilis (2004), Cavallaro and Ciraolo (2005), Su et al., (2007), Hung, et al., (2007), Khan and Faisa (2008), Tseng et al. (2008) and Tseng (2009). Therefore, this study develops the proposed criteria according to the four directions from the literatures.

2.2 Interpretive structural modeling

ISM is an interactive learning process in which a set of different and directly related elements is structured into a comprehensive systemic model (Warfield, 1974). It formed portrays the structure of a complex issue or problem, a system or a field of study, in a carefully designed pattern implying graphics as well as words. ISM methodology helps to impose order and direction on the complexity of relationships among elements of a system. There are in the various literatures in its application.

Huang et al. (2005) proposed multidimensional scaling though divide a complex system into subsystems due to of these subsystems usually exist interdependence and feedback, the weights of the subsystems are hard to obtain. Huang et al. proposed to combine the methods of ISM and the analytic network process to deal with the problem of the subsystems interdependence and feedback. Agarwal et al. (2007) used ISM to categorize according to the variables with driving and dependence power and provides a means by which order can be imposed on the complexity of such variables that help the management in strategic planning for improving supply chain agility.

Kannan et al. (2009) developed to guide the selection process of best third-party reverse logistics providers. The interactions among the criteria are also analyzed before arriving at a decision for the selection of from among 15 providers through ISM and fuzzy technique for order preference by similarity to ideal solution to the case model in India. In traditional statistical approach, structural equation modeling (SEM) is an extremely flexible linear-in-parameters multivariate statistical modeling technique. It has been used in modeling travel behavior and values since about 1980, and its use is rapidly accelerating, partially due to the availability of improved techniques. Hussey and Eagan (2007) used SEM to test environmental performance model in small and medium-sized manufacturers.

Recently studies, Tseng (2009) proposed a hierarchical structure and multi-criteria decision making (MCDM) to approach on which requires a large number of criteria. Though, the study of Tseng proposed an effective solution based on hybrid method to assist the expert group evaluating on MSWM issue. Moreover, Tseng and Lin (2009) proposed the Decision Making Trial and Evaluation Laboratory not only can convert the relations between cause and effect of criteria into a model but also can be used as a way to handle the inner dependences within a set of criteria and studies on the post survey is further discussed and proved the validity result. Nevertheless, there is none literatures using qualitative approach and applies ISM method in environmental assessment. In order to solve the study objective, this study applies an effective solution based on ISM approaching to assist the expert group to compose the MSWM hierarchical framework and results in driving and dependence power. Section 3 presents the measures of this study.

3 Proposed MSWM criteria

The section aims to identify the theoretical composition that be considered in this study’s objectives. Researchers have described MSWM as a strategic, decision making perspective in order to improve present performance. MSWM has received more attention in recent years, there are literatures dealing with how to build a sound MSWM evaluation measures for cities. This study discusses these MSWM criteria in below.

Morrissey and Browne (2004) proposed that a sustainable MSM model should not be only environmentally effective and economically affordable but also socially acceptable. Karagiannidis and Moussiopoulos (1998) proposed a set of multiple criteria, which cover social, environmental, financial, and technical aspects, for dealing with optimization of regional MSW. Su et al. (2007) studied many modern decision making support systems which already partially consider social factor analysis in addition to expenses and benefits, environmental effects, technical issues, and management aspects. Garfi et al. (2009) applies the general criteria for human development to study different waste management solutions in Saharawi refugee camps (Algeria) and to test the feasibility of a decision-making method developed to be applied in particular conditions in which environmental and social aspects must be considered, and presents the equilibrium between social, environmental and technical impacts (UNEP, 2008).

A human development aspect is presented that the human life should be oriented towards continual improvement. For this, the human development should be clearly defined the technical characteristics should understand as a strategic weapon for local resources consumption and reproducibility (C1); compatibility with environmental and geological characteristics (C2); environmental impacts should be aware with atmospheric emissions (C3); water pollution and wastewater (C4); Waste production (C5); safety and health at work (C6); land use and occupation (C7) and Landscape impact (C8). And there are three criteria for natural resources & eco-system which are fuel or non-renewable energy consumption (C9); water consumption (C10); non-renewable raw materials use (C11); Economical aspect is signifying to select an optimal alternative, capital and operational costs play an important role and preferences respect for local culture (C12); acceptable time collection (to avoid health or environment risks) (C13); percentage of collection and population served (C14); separated management of organic, hazardous or recyclable waste (C15) (Hung et al., 2007; Khan and Faisa, 2008). Moreover, social aspect is explained that MSWM has acceptance from people from all quarters, community, political, health and environmentally conscious groups. Hence, the local community participation (C16), access to technology for all members of local community (C17), living conditions of local community (C18) are proposed as criteria (Garfi et al., 2009; Tseng et al., 2009b; Tseng and Lin, 2009).

MSWM within a set of dependence relations criteria are broad terms form nature of management. These evaluation criteria integrated and find the relevant literatures, activities or components or characteristics. Table 1 presented the study MSWM structure description encountered. In this problem, the assessment in the context of cities history be collected through an extensive literature review and data. Particularly, to what criteria have enabled to sustain in this assessment. The assessment is proposed as follows.

Table 1, MSWM criteria

Goal	Criteria
MSWM criteria	Local resources consumption and reproducibility(C1)
	Compatibility with environmental and geological characteristics (C2)
	Atmospheric emissions(C3)
	Water pollution and wastewater(C4)
	Waste production(C5)
	Safety and health at work (C6)
	Land use and occupation(C7)
	Landscape impact(C8)
	Fuel or non-renewable energy consumption(C9)
	Water consumption(C10)
	Non-renewable raw materials use(C11)
	Respect for local culture(C12)
	Acceptable time collection (to avoid health or environment risks) (C13)
	Percentage of collection and population served(C14)
	Separated management of organic, hazardous or recyclable waste(C15)
	Local community participation(C16)
	Access to technology for all members of local community(C17)
	Living conditions of local community(C18)

4 Research method

This study gathers the relevant qualitative information, and composes the quadrant map for the result. Hence, the first phase is to define the decision objectives- here is to evaluate of MSWM with qualitative preferences. In empirical study, it is required to generate and establish evaluation criteria in current scenario, which is a chain (interrelations) of the criteria. The proposed 18 criteria are used to be considered in MSWM from prior literatures. Moreover, the criteria cluster has to dependence and also the relations are described in natural language. The hierarchical structure and interrelations can be obtained by (i) assigning the relations to the criteria and their associated x_i criteria (x_{ij}, $i=1,2,$, x_j) and (ii) assessing the interrelations rating of its associated criteria. This study proposes the ISM technique approach, followed by the proposed application procedures.

4.1 Interpretive structural modeling

The theory of ISM is based on discrete mathematics, graph theory, social sciences, group decision-making, and computer assistance. The procedures of ISM are begun through individual or group mental models to calculate binary matrices, also called relation matrix, to present the relations of the criteria Warfield (1974). However, Delphi method is a technique to arrive at a group position regarding an issue under investigation, the Delphi method consists of a series of repeated interrogations, usually by means of questionnaires, of a group of individuals whose opinions or judgments are of interest. After the initial interrogation of each individual, each subsequent interrogation is accompanied by information regarding the preceding round of replies, usually presented anonymously. The individual is thus encouraged to reconsider and, if appropriate, to change his previous reply in light of the replies of other members of the group. After two or three rounds, the group position is determined by averaging. The method step is as following:

1.Provision for the inclusion of the scientific criteria;
2. Means for exhibiting a complex set of relations;
3. Means for showing that complex set of relations which permit continuous observation, questioning and modification of the relations;
4. Congruence with the originators' perceptions and analytical processes;
5. Ease of learning by public (or, by inference, multidisciplinary) audience.

Graphical models or, more specifically, directed graphs (digraphs) appear to satisfy these requirements. In such a representation, the criteria of a system are represented by the "points" of the graph and the existence of a particular relationship between criteria is indicated by the presence of a directed line segment. It is this concept of relatedness in the context of a particular relation which distinguishes a system from a mere aggregation of criteria. A relation matrix can be formed by asking the question like "Does the feature e_i inflect the feature e_j ?" The general form of the relation matrix can be presented as follows:

$$D = \begin{array}{c} \\ e_1 \\ e_2 \\ . \\ . \\ e_n \end{array} \begin{array}{c} \begin{array}{ccccc} e_1 & e_2 & \cdots & \cdots & e_n \end{array} \\ \begin{pmatrix} 0 & d_{12} & \cdots & \cdots & d_{1n} \\ d_{12} & 0 & \cdots & \cdots & d_{2n} \\ \cdots & \cdots & \cdots & \cdots & . \\ \cdots & \cdots & \cdots & \cdots & . \\ d_{m1} & d_{m2} & \cdots & \cdots & 0 \end{pmatrix} \end{array}$$

Where e_i is the i th criterion in the system, d_{ij} denotes the relation between i th and j th criterion, $\boldsymbol{D}$ is the relation matrix. After constructing the relation matrix, we can calculate the reachability matrix using Eqs. (1) and (2) as follows

$$M = D + I \quad (1)$$

$$M^* = M^k = M^{k+1} \quad k>1 \quad (2)$$

Calculates the reachability and the priority set bases on Eqs. (3) and (4), respectively, as the following equations

$$A\ (t\ i) = \{\ t_j\ \mid m'_{ij} = 1\} \quad (3)$$

$$R\ (t\ i) = \{\ t_j\ \mid m'_{ij} = 1\} \quad (4)$$

where m_{ij} denotes the value of the ith row and the jth column.

According to Equation (5), the levels and relations between the criteria can be determined and the structure of the criterion's relations can also be expressed using the graph. R represents the intersection of antecedent set and reachability set.

$$R\ (ti) \cap A\ (ti) = R\ (ti) \quad (5)$$

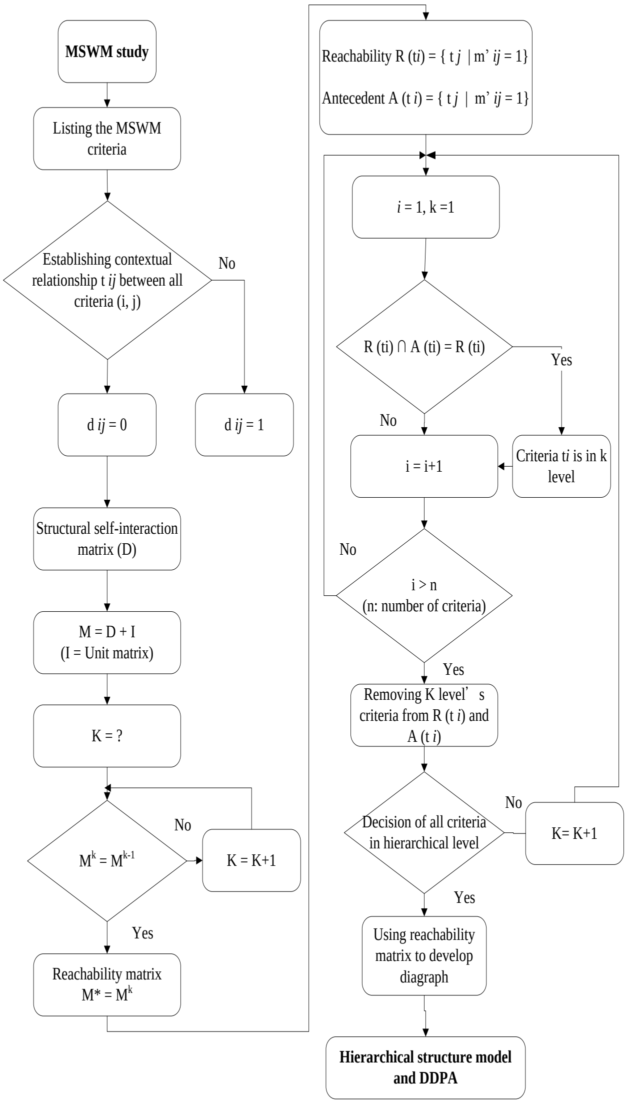

Fig.1, ISM flowchart

4.2 Dependence - driving power analysis

Ultimately, this study followed the flow chart to result the hierarchical model. The interpretation of structure needs to apply dependence - driving power analysis (DDPA). A DDPA is to draw implications for managing the criteria. It identifies the relative the dependence and driving power of the criteria associated with MSWM while at the same time indicating the degree of dependence and driving power ranking (Martilla and James, 1977). The results are plotted graphically on a four-dimensional grid, in which the driving power of the criteria is displayed on the vertical axis while the dependence power level is displayed on the horizontal axis into four quadrants. The quadrants are labeled as: Autonomous criteria, Dependent criteria, Linkage criteria and Independent criteria.

First quadrant includes criteria (autonomous criteria) that have weak driver power and weak dependence. These criteria are relatively disconnected from the system, with which they have only few links, which may be strong. Second quadrant (named: dependent criteria) consists of criteria that have weak driving power but strong dependence. Criteria in third quadrant have strong driving power and strong dependence. These criteria fall into the category of independent or linkage criteria. These criteria are unstable which presented any action on these criteria have an effect on others and also a feedback effect on themselves. Fourth quadrant includes independent criteria having strong driving power but weak dependence. Using simple visual analysis, the quadrant evaluation grid reveals strengths and weaknesses of the criteria under consideration and so draws managerial implications for resource allocation. The competitive positions are identified, and further improvement strategies are discussed.

4.3 Proposed approach

1. Identify the inter-relationships among criteria. It is a suitable modeling technique for analyzing the influence of one criterion on other criteria. It provides systemic approach for improving MSWM performance. “A” presented criteria *i* will help to achieve criteria *j*; “B” presented criteria *j* will be achieved by criteria *i*; “C” presented criteria *i* and *j* will help achieve each other; and “D” presented criteria *j* and *i* are unrelated. Using Eqs. (1) and (2) to arrive the reachability matrix.
2. Interpretive as the judgment of the group decisions whether and how the criteria are related. An overall structure is extracted from the complex set of criteria. Transformed into a reachability matrix format by transforming the information in each entry of the linguistic preferences into 1s and 0s in the reachability matrix. The situations are as follows:
   1. If the (*i*, *j*) described is A, the (*i*, *j*) described in the reachability matrix becomes 1 and the (*j*, *i*) entry becomes 0.
   2. If the (*i*, *j*) described is B, the (*i*, *j*) described in the matrix becomes 0 and the (*j*, *i*) entry becomes 1.
   3. If the (*i*, *j*) described is C, the (*i*, *j*) described in the matrix becomes 1 and the (*j*, *i*) entry also becomes 1.
   4. If the (*i*, *j*) described is D, the (*i*, *j*) described in the matrix becomes 0 and the (*j*, i) entry also becomes 0. Following these rules, initial reachability matrix for the criteria is established.
3. Starts with an identification of criteria, which are relevant to the MSWM issue and then extends

with a group problem-solving technique. Then a contextually relevant subordinate relation is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix is developed based on pair-wise comparison of variables. Applied Eqs. (3), (4) and (5) to arrive the hierarchical levels of criteria.

4. Using visual analysis DDPA evaluation grid to draw the four quadrants for the proposed criteria, the evaluation grid reveals functions of the criteria in MSWM.

5 Empirical study

The proposed criteria are applied to evaluate the MSWM in Taipei metropolitan. The population density of Taipei metropolitan is the highest in Taiwan. Taipei metropolitan is well managed the MSWM, however the identified of importance and performance has to be done in a period of time. In this study, ISM has been applied to develop a hierarchical framework for MSWM in Taipei to achieve the following broad objectives:

- To derive interrelationships among the criteria affecting MSWM, and
- To classify the criteria according to their driving and dependence power.

In the present paper, ISM has been applied to show the interrelationships of different criteria of MSWM. This study follows the four proposed steps to analyze the data from the group of experts. The group of expert included five academicians and five practitioners from the department of environmental protection of Taipei (City and County) government. The data analysis and the results are addressed as following.

1. Identify the interrelations among criteria. It is a suitable modeling technique for analyzing the influence of one criterion on other criteria. It provides systemic approach for improving MSWM performance. "A" presented criteria *i* will help to achieve criteria *j*; "B" presented criteria *j* will be achieved by criteria *i*; "C" presented criteria *i* and *j* will help achieve each other; and "D" presented criteria *j* and *i* are unrelated. Using Eqs. (1) and (2) to arrive the reachability matrix.

Table 2, Structural criteria interrelations matrix

Criteria	C18	C17	C16	C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2
C1	A	B	D	A	A	D	D	D	A	A	A	A	D	D	D	D	D
C2	D	D	A	A	D	D	A	A	B	A	D	D	D	B	D	D	
C3	A	A	A	A	B	B	B	D	D	D	C	D	D	D	D		
C4	D	A	A	A	B	A	D	D	D	D	C	D	C	D			
C5	D	D	D	A	A	A	A	A	D	A	D	C	D				
C6	1	D	D	D	D	D	D	A	A	A	B	A					
C7	D	D	D	D	D	D	D	D	D	B	D						
C8	1	1	1	1	D	D	D	D	D	A							
C9	D	D	D	D	D	D	D	D	D								
C10	D	D	A	A	D	A	B	A									
C11	D	D	D	A	D	D	B										
C12	D	D	D	D	D	D											
C13	D	D	D	B	D												
C14	D	D	D	D													
C15	D	D	D														
C16	D	D															
C17	A																

2. Interpretive as the judgment of the group decisions whether and how the criteria are related. An overall structure is extracted from the complex set of criteria. The matrix is partitioned, by assessing the reachability and antecedent sets for each criterion. The reachability set consists of the criterion itself and other criteria, which it may help to achieve, whereas the antecedent set consists of the criterion itself and other criteria, which help achieving it. The intersection of these sets is derived for all the criteria. The criteria for which the reachability and intersection sets are same are the top-level criteria in the ISM hierarchy. The top-level criteria would not help to achieve any other criteria above their own level in the hierarchy. Once top-level criteria are identified, it is separated out from the rest of the criteria. Then, the same process is repeated to find the next level of criteria. These identified levels help in building the digraph and final model. In the present case, the criteria along with their reachability set, antecedent set, intersection set and the levels are shown in Table 2.

Table 3, Initial reachability matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18
C1	1	1	0	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0
C2	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0
C3	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
C4	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	1	1	1	1	1	1	1	0	0	0	1	0	0	1	1
C6	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0
C7	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	1
C8	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	0	0	0
C9	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1
C10	0	0	1	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0
C11	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0
C13	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
C16	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	1	1	1
C17	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1
C18	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1

3. Starts with an identification of criteria, which are relevant to the MSWM issue and then extends with a group problem-solving technique. Then a contextually relevant subordinate relation is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix is developed based on pair-wise comparison of variables. Applied Eqs. (3), (4) and (5) to arrive the hierarchical levels of criteria.

Table 4, Levels of MSWM criteria

Criteria	Reachability	Antecedent	Intersection	Level
C1	1,2,4,5,9,10,11,12,	1,2,5,6,7,8,14,15,16,17,18	1,2	IV
C2	3,4,7,8,9,10	1,3,4,6,7,8,9,14,15,16,17,18	3,4	III
C3	1,2,3,4, 5,6,7,8,9	3,5, 6,7,8,14,15,16,17,18	5	III
C4	2,3,4,5,6	1,2,3,5,6,7,8,10,11,12,13	6	IV
C5	4,5,6,7,8,9,10, 14,17,18	7,11	7	IV
C6	1, 8,9,10,11,12,13,14,15,16	3,5,6, 8,9	8,9	V
C7	10,12,13,14,15,16,18	10,17	10	I
C8	1,2,3,4, 10,11,12,13,14,15	2,3,5,6,7,8,9,11	11	I
C9	10,11,14,15,16,17,18	1,2,3,5,10,11	10,11	I
C10	3, 6,7,8, 10, 11	10,11,12,14,15,16,17,18	10,11	I
C11	4,8,9, 12	12,14,15,17,18	12	II
C12	10,11,12,13	1,5,6,7,8,9,11,12,14,15	11,12	II
C13	4,13,14,15,16,17,18	3,5,6,7,8,12,13,14,15	13,14,15	V
C14	10,11,12,13,14,15,16,18	3,5,6,7,8,13,14,15	13,14,15	V
C15	14,17,18	1, 5,6,7,13,14,16	14	V
C16	8,9,10,15,16,17,18	6,7,13,14,15	15	V
C17	1,2,3,8,9,10,11,16,17,18	5,7,13,15,16,17,18	16,17,18	VI
C18	1,2,3,8,9,10,11,16,17,18	5,7,13,14,15,16,17,18	16,17,18	VI

4. Using DDPA to approach the evaluation grid to draw a four quadrants visual analysis for the MSWM criteria, the evaluation grid reveals functions of the criteria. First quadrant includes criteria (autonomous criteria) that have weak driver power and weak dependence. Those criteria are land use and occupation (C7); local culture (C12); acceptable time collection to avoid health or environment risks (C13); access to technology for all members of local community (C17) and living conditions of local community (C18), relatively disconnected from the system, with which they have only few links. Second quadrant (named: dependent criteria) consists of criteria that have weak driving power but strong dependence which are waste production (C5); safety and health at work (C6);percentage of collection and population served (C14); separated management of organic, hazardous or recyclable waste (C15) and the local community participation (C16).

Moreover, third quadrant (named: linkage criteria) has strong driving power and strong dependence. Those are environmental impacts should be aware with atmospheric emissions (C3) and landscape impact (C8). These criteria fall into the category of linkage criteria. These criteria are unstable which presented any action on these criteria have an effect on others and also a feedback effect on themselves. Therefore, providing its MSWM performance with more goal and prior to sustainable development aspect must be considered with a top priority. Fourth quadrant includes independent criteria having strong driving power but weak dependence, which are local resources consumption and reproducibility (C1); compatibility with environmental and geological characteristics (C2); water pollution and wastewater (C4); fuel or non-renewable energy consumption (C9); water consumption (C10) and non-renewable raw materials use (C11) Using simple visual analysis, the quadrant evaluation grid reveals strengths and weaknesses of the criteria under consideration and so draws managerial implications for resource allocation. The competitive positions are identified, and further improvement strategies are discussed.

Table 5, Driving and dependence power in reachability matrix

	C10	C8	C9	C18	C4	C14	C11	C17	C3	C1	C2	C15	C12	C16	C13	C5	C6	C7	Driving power
C3	1	1	1	0	1	0	0	0	1	1	1	0	0	0	0	1	1	1	10
C5	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	1	1	10
C6	1	1	1	0	0	1	1	0	0	1	0	1	1	1	1	0	0	0	10
C8	1	0	0	0	1	1	1	0	1	1	1	1	1	0	1	0	0	0	10
C17	1	1	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	9
C18	1	1	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	9
C1	1	0	1	0	1	0	1	0	0	1	1	0	1	0	0	1	0	0	8
C7	1	0	0	1	0	1	0	0	0	0	0	1	1	1	1	0	0	0	7
C9	1	0	0	1	0	1	1	1	0	0	0	1	0	1	0	0	0	0	7
C16	1	1	1	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	7
C2	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	6
C10	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	1	6
C13	0	0	0	1	1	1	0	0	0	0	0	1	0	1	1	0	0	0	6
C4	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1	0	5
C11	0	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	4
C12	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	4
C14	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	3
C15	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	3
Dependence power	13	9	9	9	8	8	8	7	7	6	6	6	6	5	5	4	4	4	

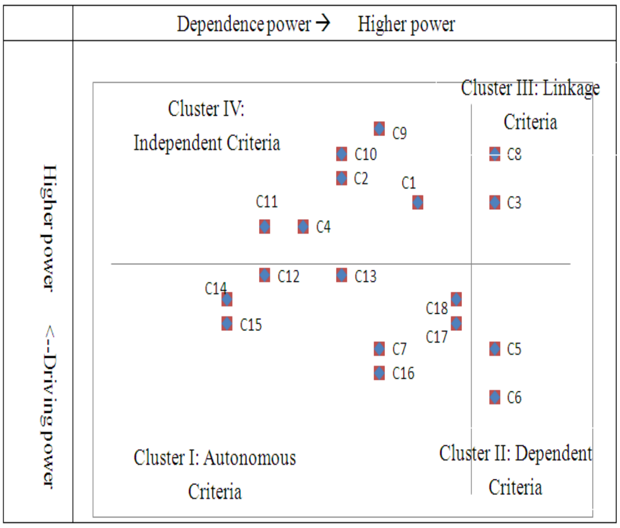

Fig.2, Cluster of criteria for improving MSWM

The results of the study indicate that the top-level criteria, having strong driving power, those are local resources consumption and reproducibility (C1); compatibility with environmental and geological characteristics (C2); fuel or non-renewable energy consumption (C9) and water consumption (C10). Besides, atmospheric emissions (C3) and landscape impact (C8) have strong dependence on other criteria, called linkage criteria. The improved level of top-level criteria helps to enhance MSWM. Therefore, management of the Taipei metropolitan should focus its attention to build up a strong agent through better use of aforementioned criteria. For example, local resources consumption and reproducibility (C1); compatibility with environmental and geological characteristics (C2); environmental impacts should be aware with atmospheric emissions (C3); water pollution and wastewater (C4) and acceptable time collection to avoid health or environment risks (C13) are criteria having a medium driver power and medium dependence. These criteria need consistent attention of the management in enhancing MSWM. Management should always keep a watch on the level of these criteria. Slight variation in the level of these variables may severely affect the MSWM. Criteria like use of waste production (C5); safety and health at work (C6); land use and occupation (C7) and the local community participation (C16) are criteria having weak driving power. These criteria have none the capability to condition the whole MSWM and can be called Autonomous or Dependent criteria.

6 Concluding remarks

This study was to provide a full account of such an inextricably complex phenomenon as vagueness and dependence relations among the criteria, but the study goal is worth a precise and thorough study to positioning the criteria as a strategic direction of MSWM. At present, exploring the MSWM of Taipei metropolitan is the intention to provide some practical implications to the management who are eager to probe the relevant strategies, especially to build a hierarchical model and understand the relations among the critical criteria. In addition, the expert group remarked on the merits and drawbacks of the proposed solution. Unlike a traditional hierarchical model based on the linear and piecemeal approach, the modified ISM is novel since it is based on complex dependence relations among the criteria in linguistic approach. Moreover, it is favorable to handle the problem of dependence of criteria, linguistic preference and model a hierarchical structure since it can provide more valuable information for strategic direction (Sarkis, 2003; Tseng et al., 2008). The following section is devoted to that purpose.

First of all, the improvement plan might derive from linkage criteria quadrant. Specifically, to position the criteria approaches to direct their goal and practices the sustainable development concept to attain the goal. This is particularly crucial for the management that focuses on the criteria to satisfy environmental requirements to improve their citizen's living quality. In order to assess the criteria and effectiveness of the proposed solution, the study uses the DDPA to develop a positioning visual strategy. It was well noted that MSWM must devise with a set of criteria and considers what is most valued among the measures. Many works related to provide valuable advice, including essential criteria for a successful direction (Su et al. 2007; Vego et al. 2007; Khan and Faisal 2008). Few works provided methods which can empirically evaluate and hierarchical model the MSWM involved with several complex criteria systematically for Taipei metropolitan. Hence, this study proposes an effective solution that can position the criteria in an analytical manner.

Second, give higher driving power in top three criteria, which are landscape impact; fuel or non-renewable energy consumption and water consumption to position the MSWM criteria in evaluation. The result is indicated that the criteria are located in the independent and linkage criteria quadrants in the management of Taipei metropolitan. Moreover, with higher dependent power are atmospheric emissions; waste production; safety and health at work and landscape impact. The overlapping of driving and dependence power is the landscape impact (C8), which means this criterion is with higher driving and dependence power.

Lastly, the contribution is to build a visual map and to evaluate MSWM with driving and dependence power successfully, none of prior study is able to systematically evaluate and construct the proposed criteria into a hierarchical framework and visual map. Furthermore, the government agent might apply this approach to evaluate and determine the driving and dependence powers to reduce the management risks. In conclude, this study contributes to, in particular, the literatures by: (i) construct a MSWM hierarchical framework; (ii) developing multi-criteria measures for MSWM and bases on linguistic preferences.

As knowledge takes on an important strategic role, governments expect the MSWM to be performed effectively and efficiently and transfer into national competitive advantages in sustainability environment. However, this approach is a novel method that can deal with many criteria interactive problems systematically, unlike traditional approaches are always applied independence assumption. In order to promote and deepen continuing research in future, it is worthwhile to investigate more cases in deep to uncover invaluable new issues to be studied further. In addition, the assessment criteria can be improved as different status suffered. ISM is a tool for management to understand the criteria behavior of MSWM. This study uses perception of the experts to generate a result that might help for the management to drive the efforts towards the roots of the problem. This ISM approach is a novel approach to generate a visual map for the management to justify the driving and dependence power of proposed criteria. However, landscape impact acts as a higher driver and dependence power for the management to focus on MSWM. This implies that use of the criteria as tool, to be the process integrator and work as the driver in effective MSWM integration.

Only eighteen criteria are identified and constructs into the hierarchical framework. More number of criteria can be identified to evaluate in ISM approach. The respondents are used linguistic preferences to analyze driving and dependence power into a visual map. This approach depends upon the opinion of experts and has somehow bias might happen. However, this model has not been numerical validated. Analytical network process (ANP) can be used to examine the consistency index and consistency ratio (Tseng et al. 2009a). ANP provides a more generalized model without making assumptions about the independence of the aspects and criteria in a hierarchical framework. Moreover, Structural equation modeling, also commonly known as linear structural relationship approach has the capability of testing the validity of such hypothetical model. Therefore, the future approach might test and enhance the validity of this framework.

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