Stakeholder Analysis Together with GIS and MCDA for Decision making in Municipal Solid Waste Management of Local Administrations of Thailand

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Abstract
MSW management is the universal problem every country is facing due to its ever-increasing quantity of daily solid waste, environmental impact on sites, and vulnerability along transportation routes. Fortunately, technology and method such as GIS and MCDA have been recently found efficient to assist in the management. With additional stakeholder participation, the management can significantly compromise conflicts and promote the sustainability. This article focuses on proposing a new composite of spatial analytical tools and concepts of GIS, MCDA, and stakeholder participation for well-organized MSW management. As a case study, stakeholder analysis was performed in major local administrative areas of Thailand where several new problems were encountered that required new solutions involving geospatial technologies. Salience model and Mamdani's FIS were appropriately used in the analysis to deal with stakeholder opinions which are fuzzy by nature. The analysis resulted in groups of relevant stakeholders, their priority levels, role characteristics, and preferences which influence waste management.

1. Introduction

Due to rapid urbanization, solid waste management has become a major concern in several developing countries including Thailand (Nachalida et al., 2017). The ever-increasing economic development and growing population from 48 million in 1982 to 68.86 million in 2016 of Thailand have resulted in the generation of a huge quantity of municipal solid waste (MSW) (Chiemchaisri et al., 2008). This has led to many problems pertaining to waste transportation as well as waste disposal management. The waste management methods have to be environmentally safe and economically sustainable (Ghose et al., 2006). For years the management has been a topic for heated debates. It has both positive and negative impact on different groups of stakeholders. The Thai National Waste Management policy encourages local administrations to organize as clusters and establish central MSW disposal facilities with suitable technologies to reduce the cost of disposal and transportation. It should be an integrated approach to both environmental and economic sustainability (Kaosol, 2009 and Nachalida et al., 2017). To achieve this objective, the optimum control of the waste management system is required. Apart from using services of selective disposal sites available in the areas, a proper transportation management can reduce environmental impact on transfer stations (TSs) and disposal sites (DSs) including vulnerability along the transportation route. The management deals with waste amount allotment and allocation from TSs to DSs so that the waste can be disposed in a timely manner making sure that the cost, vulnerability along routes, and impact of sites (DSs) are minimized.

Waste transportation management can be carried out successfully using Geographic Information System (GIS). Network Analysis (NA) of GIS can provide optimum routes of all TS-DS pairs. Environmental impact indexes of sites can be evaluated using Multi-Criteria Decision Analysis (MCDA) through GIS system. Groups of criteria corresponding to policy and environmental characteristics of sites can be identified, scored and weighted, and then integrated to impact indexes. It is enhanced by multiplication of waste amount in service. GIS techniques are used to assess vulnerability along the route. Linear programming (LP) of MCDA is a multi-objective decision tool used to analyze waste allotment and allocation from TSs to DSs to meet the objectives. Patterns of waste transportation are different from objective to objective. The pattern is characterized by waste allotment and allocation from TSs to active DSs, total transportation cost, environmental impact and vulnerability, including optimum routes. These patterns are ranked based on their characteristics and stakeholder preferences utilizing Preference Ranking Organization Method for Enrichment Evaluations

(PROMETHEE) (Coban et al., 2018, Charisios et al., 2013 and Makan and Mountadar, 2013).

A stakeholder is defined as a person, organization or group of people, which may either get affected or influenced by a problem or by its solution (Hermans et al., 2011). Stakeholders can be anyone at any level in a society who shares a common interest or has the stake in a particular issue or system (Grimble and Wellard, 1997). The agreement between all the groups on the basis of their priority levels would assist to legitimately compromise in any conflicts. The experience in several countries has shown that cooperation and coordination among different stakeholder groups will result in increasing the sustainability of waste management (dos Muchangos et al., 2017 and Geneletti, 2010). At the local level, they can play a crucial role in assisting policy makers in defining an effective and long-running waste management plan (Sisto et al., 2017). Hence for effective planning and successful participation, the analyses of stakeholders are therefore required. The analysis will result in the identification of groups of relevant stakeholders and their preferences on activities including their priority level and role characteristic.

For stakeholder analysis, Salience model was developed to deal with scoring and classifying crucial roles of stakeholder groups as per the attributes of power, urgency, and legitimacy (Poplawska et al., 2015 and Mitchell et al., 1997). By nature, profile scores assigned to each other group are fuzzy scores of these attributes. A de-fuzzied profile score will be further identified to be fuzzy linguistic class. This de-fuzzied score has a chance to fall into one or two fuzzy classes which leads to the requirement of rules to agglomerate classes. The agglomeration of fuzzy classes and rules following by de-fuzzification can be operated by Mamdani's Fuzzy Inference System (FIS). The final result is a set of stakeholder preferences.

2. Local Administrations of Phitsanulok as the Study Area

Phitsanulok province, Thailand, is a good representative of big provinces in the northern region of Thailand. The province consists of 102 local administrations and generates about 860 tons of MSW per day. Recently, it has been encountering difficulty in seeking an efficient solution for waste management. Environmental Office Region 3 (EOR3, 2013) has reported that only 37 local administrations have proper and systematic service on waste management, while others have no such a service. The study area is located in Mueang district. It consists of 11 Subdistrict Administrative Organizations and Municipalities. The area covers approximately 300 km^2 (Figure 1).

There have been 11 active waste disposal sites, landfill and controlled dump, available for handling all solid waste generated recently in the study area. To this date, there is no serious requirement for the additional waste disposal site. The existing active disposal sites are located within 30 km away from the study area. According to the suggestion of Pollution Control Department (PCD), this is at the boundary distance in economic point of view for waste transportation (PCD, 2014). In the past, the major governmental institutions officially responsible for waste management in the study area include EOR 3, Provincial Offices for Natural Resources and Environment Phitsanulok (PONRE), and Local Administrative Organization (LAO). Recently, the 4th Infantry Division of the Royal Thai Army (RTA), an Adhoc team, has become active and forces positive change on transforming open dumps to be controlled dumps. Other groups of stakeholder so far show no active involvement. This area chiefly reflects the problem on MSW disposal due to its big amount generation and poor management. New solution perspective on waste management is required and being sought. The perspective should be sustainable management resulting in compromising conflicts, minimizing cost and environmental impact, and promoting fully involvement of stakeholders. Stakeholder analysis, GIS technology, and MCDA are proposed to be the promising combination for this new perspective. This article focuses on performing stakeholder analysis in the study area to report crucial roles of stakeholder groups on the basis of their preferences and priority levels. To be able to see the whole figure of the management, selective GIS techniques and MCDA were additionally introduced.

3. Proposed GIS Technology and MCDA for Waste Transportation Management

3.1 Network Analysis (NA)

NA is a GIS tool used to find the best route which may be the shortest, safest, or most scenic, depending on the purpose of travel (Lo and Yeung, 2002). The closest facility function in NA of ArcGIS™ is proposed to find an optimum route with the shortest distance. Input data of the analysis are locations of TSs as the origins and disposal sites as the destinations, and road network. The impedance of links in the road network is the distance. Barrier links will be set as removed links by stakeholders before input into the analysis.

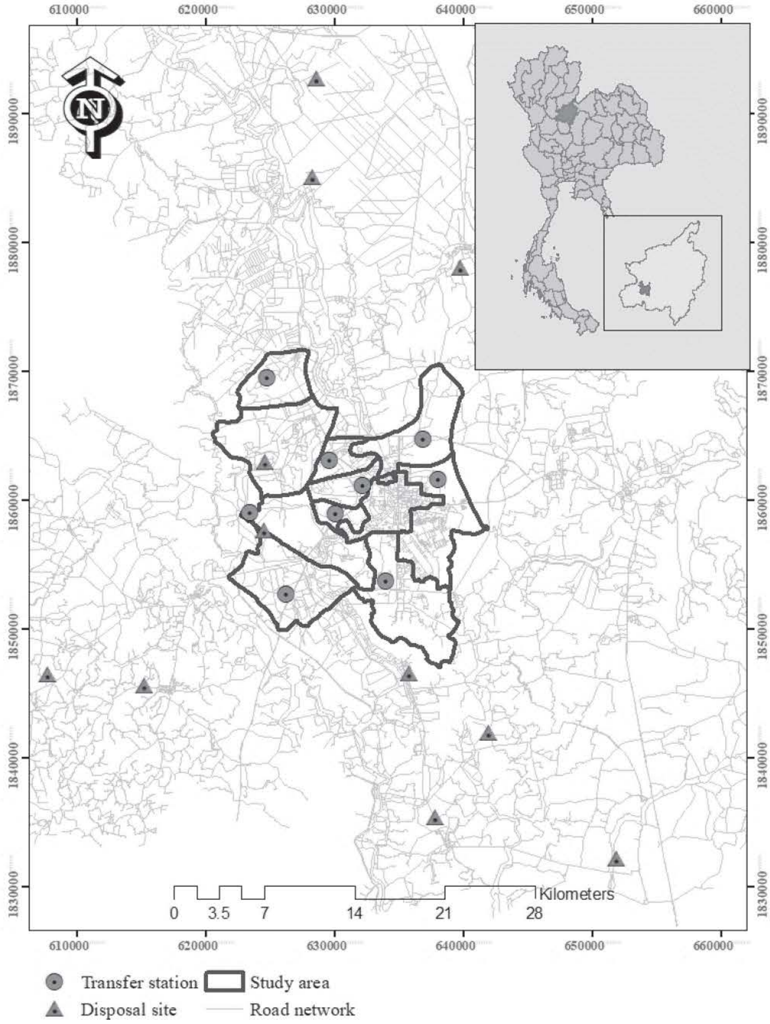


Figure 1: Study area and surrounding active disposal sites

The distances of optimum paths from each TS to each DS will be prepared in form of a matrix which will be further employed in LP analysis. The distance together with waste amount is later used to estimate transportation cost.

3.2 Linear Programing (LP) Analysis

LP analysis is the general concept dealing with programming problems for which all relations among the variables are linear, both in the constraints and in functions to be optimized (Gupta, 2009). LP, as one of MCDA tools, has been used for managing waste allotment and allocation from TSs to DSs. Objectives of LP analysis should include minimization of total transportation cost (TC), environmental impact (EI) between TSs and DSs, vulnerability (VI) on optimum routes, and their combinations under certain and varying constraints. These constraints include daily capacities of each DS, supply amount of each TS, and numbers of active TSs and DSs.

LP analysis can be operated either for single objective or multi-objectives at a time. To serve these objectives, matrixes of optimum routes, EI, and VI of TS-DS pairs will be input for LP analysis. EI matrix can be prepared based on the evaluation of both TSs and DSs. Waste amounts generated in the administrative units indicate EI of TSs. EI of DSs can be adopted from the study of Phinyoyang (2016) and Phinyoyang et al., (2017). The vulnerability of the facilities is calculated as the linear relationship between a number of people on daily service of the facility and distance to road segments (Panwhar et al., 2000). During MSW transportation, adverse impact such as odour, leachate, and the aesthetic view can still disturb people who live in close proximity and those who travel along the route. Estimated vulnerability as attributes of varied buffering areas intersecting to each optimum route multiplied by corresponding intersecting lengths is summed up to represent VI of each route.

The operation can be performed using GIS functions. The matrix of normalized VI along the optimum route of each pair of TS and DS can be prepared and further used as input for the LP analysis.

3.3 Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)

Transportation patterns obtained from LP analysis can be ranked by PROMETHEE method (Malczewski and Rinner, 2015 and Coban et al., 2018). For a proper ranking, criteria outcomes of alternatives, i.e. total TC, EI, and VI, and criteria weights incorporating with preferences of stakeholders are considered. To show stakeholder privilege, weights of criteria outcomes from interviewing of each stakeholder group will be multiplied by its preference obtained from stakeholder analysis, normalized, and averaged to be stakeholder-criteria weights. The method firstly performs the mutual comparison of alternatives in form of matrixes based on criteria outcomes of each transportation pattern. The minimum is considered the better and scored as 1, 0 otherwise. The results are multiplied by stakeholder-criteria weights and then summed up to show preference value of combined criteria of each alternative comparison in the matrix. The preference values in the matrix are aggregated in terms of leaving flow, $F^{+}(Ai)$ (along the row) and entering flow, $F^{-}(A_i)$ (along with the column). The net flow, $F(Ai) = F^{+}(A_i) - F^{-}(A_i)$, will then be calculated. The ranking will be finally performed using the net flow. The higher net flow is the higher position in the rank.

4. Methodology of Stakeholder Analysis

The stakeholder analysis includes stakeholder group identification, stakeholder group scoring based on Salience model attributes, fuzzy membership defuzzification and fuzzy linguistic classification, rule establishment and priority level identification based on rules, rule aggregation of each individual group of stakeholder, and defuzzification to obtain stakeholder preferences. The preferences of stakeholder groups were further used in PROMETHEE outranking of patterns of waste transportation management.

4.1 Stakeholder Group Identification

For any development and management project, stakeholder analysis should be performed first so that groups of stakeholder and their preferences can be identified and determined. The list of candidate groups of stakeholder was drafted according to written records and publications, synthesis of the researcher, and experts' comments (Chevalier and Buckles, 2008). The questionnaire was designed to allow involving groups to be added to or withdrawn from the list through survey and interview operating on candidate groups. Following the suggestion of Mayers (2005), the main questions for key stakeholder identification include (i) Who are potential beneficiaries? (ii) Who might be adversely affected? (iii) Who has existing rights? (iv) Who is likely to be voiceless? (v) Who is likely to resent change and mobilize resistance against it? (vi) Who is responsible for intended plans? (viii) Who has money, skills or key information? and (ix) Whose behaviour has to change for success? The answer to each question was scored from 1-5 for each individual group. Based on total scores, top five stakeholder groups were selected from each question and assimilated to be a list of key stakeholder groups.

4.2 Characterization of Stakeholder Group using Salience Model and Mamdani's FIS

Stakeholder groups can be characterized in terms of their priority levels, roles, and preferences. Salience model can be used to explain the role and the priority level of stakeholder according to three major attributes, namely power, legitimacy, and urgency (Mitchell et al., 1997). Power is to influence the organization or project deliverables (coercive, financial or material, brand or image). Legitimacy indicates the relationship and actions in terms of desirability, properness or appropriateness. Urgency informs the requirements in terms of criticality and time sensitivity for the stakeholder. Based on the combination of these attributes, the role of stakeholder groups can be classified into 7 characteristics with 3 priority levels as shown in Figure 2 (Mitchell et al., 1997).

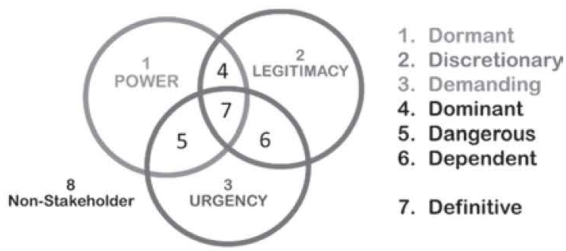


Figure 2: Role characteristics of stakeholder group in Salience model (Mitchell et al., 1997)

Definitive (7), the high priority group, shows role characteristic covering all 3 attributes; while Dominant (4), Dangerous (5), and Dependent (6), the medium priority group, covering 2 attributes; and Dormant (1), Discretionary (2), and Demanding (3), the low priority group, covering only 1 attribute. According to Poplawska et al., (2015), to characterize stakeholder group successfully, Salience model and Mamdani's FIS were operated based on 2 phases as displayed in Figure 3. The first phase was deconstructed into 2 steps and followed by 3 steps in the second phase.

Phase 1: Stakeholders' Salience Calculation

1) Evaluations: Respondents were asked to evaluate the importance of every stakeholder with respect to the attributes of power, legitimacy and urgency on a Likert scale ranging from0 (none) to 3 (high) with the intermediate levels 1 (low) and 2 (medium).

2) Respondents' aggregation and defuzzification: The evaluations of all respondents in terms of 3 attributes were aggregated into a unique score by calculating the average value. The upper and lower in range (maximum and minimum) of each attribute were also taken. The profile scores of groups of stakeholder were obtained by defuzzification of each attribute using equation of the weighted average method:

$$Y = (min_i + 2*average + max_i)/4$$

Equation 1

Phase 2: Stakeholder priority determination

The second phase was to determine stakeholder priority by Mamdani's FIS. The system is often applied in a sustainability context as it is intuitive and allows appropriate modelling of human input (Phillis and Andriantiatsaholiniaina, 2001).

1) Fuzzy linguistic classification of stakeholder group: The trapezoidal functions were used to convert profile score of each attribute of each stakeholder group to be fuzzy class as displayed in Figure 4((a) and (b)).

2) Salience fuzzy classification of role and priority level using rule base: The fuzzy if - then rules (Table 1) were developed by Poplawska et al., (2015) showing relationship of fuzzy classes of 3 attributes and Salience priority levels. The rules also identify role characteristics of stakeholder groups falling into those rules. The Salience priority classes in linguistic fuzzy terms (low, medium, and high) are displayed in Figure 4(c).

3) Rule aggregation and defuzzification of stakeholder preferences: Aggregation of each combination of 3 attributes based on Salience rule(s) (Table 1) was operated using fuzzy Min. In case a profile score of anyone of attributes falls into more than a fuzzy class, more than one rule can be active. Aggregation of Salience priority classes (after fuzzy Min operation) of active rules must then be operated using fuzzy Max. This aggregated result of each stakeholder was defuzzified using the center of gravity (COG) method. The defuzzified scores indicate stakeholder preferences and can be used in further MCDA for any purposes required by certain activities.

5. Result and Discussion

5.1 Stakeholder Identification

From an inventory of 16 candidate stakeholder groups, questionnaires containing questions of Mayers (2005) were distributed among stakeholder groups to respond and resulted in 15 groups selected, as listed in Table 2. Scores in percentage indicate how much more or less they should involve in the activity. However, these scores will not directly express their significance of roles and preferences.

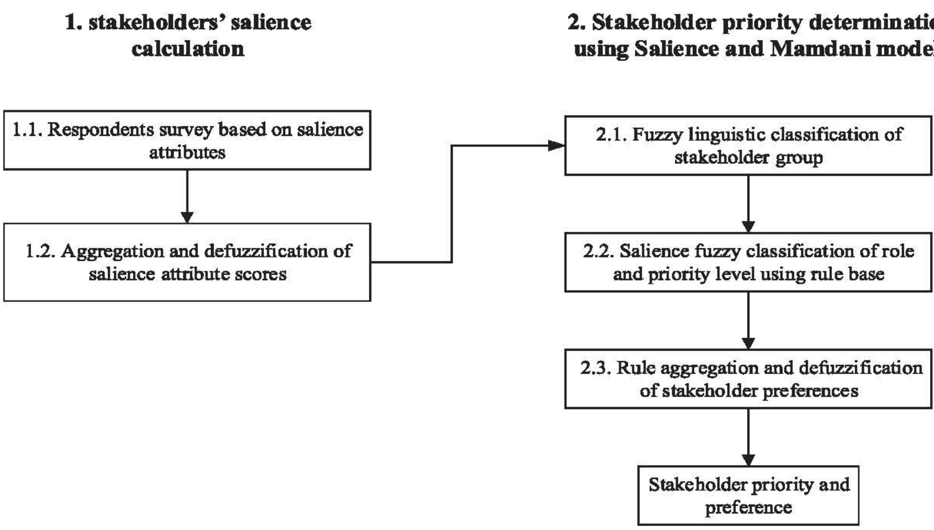
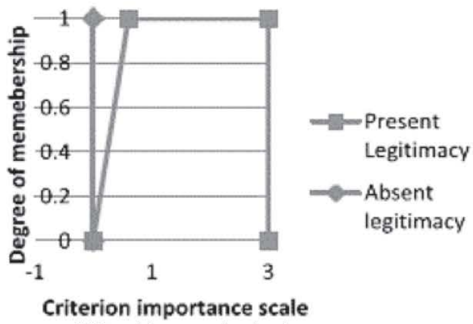


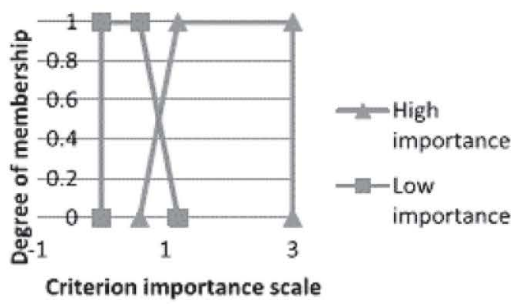
Figure 3: Stakeholder analytical processes using Salience model and Mamdani's FIS

Table 1: The salience fuzzy if-then rules (Poplawska et al., 2015)

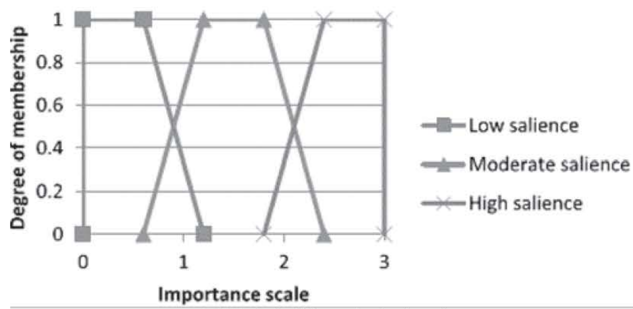
Salience priority	**If-then rules applied in the study**		
	Rule no.	**Antecedent part**	**Consequent part**
Low	1	If legitimacy is absent and power is high and urgency is low	Then stakeholder is Dormant
	2	If legitimacy is present and power is low and urgency is low	Then stakeholder is Discretionary
	3	If legitimacy is absent and power is low and urgency is high	Then stakeholder is Demanding
Moderate	4	If legitimacy is present and power is high and urgency is low	Then Stakeholder is Dominant
	5	If legitimacy is absent and high and urgency is high	Then stakeholder is Dangerous
	6	If legitimacy is present and power is low and urgency is high	Then stakeholder is Dependent
High	7	If legitimacy is present and power is high and urgency is high	Then stakeholder is Definitive
None	8	If legitimacy is absent and power is low and urgency is low	Then stakeholder is non stakeholder



(a) Legitimacy criterion importance



(b) Power and Urgency criteria importance



(c) Stakeholder priority level

Figure 4: The membership functions of the linguistic classification of attributes ((a) and (b)) and Salience priority levels of stakeholders (c) (Poplawska et al., 2015)

5.2 Characterization of stakeholder groups using Salience model and Mamdani's FIS

Phase1: Stakeholder's profile scores

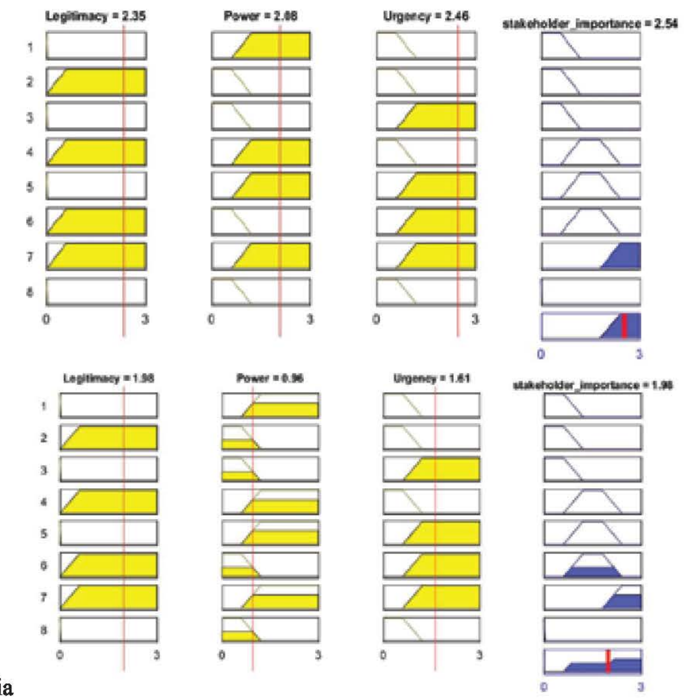
Poplawska et al., (2015) suggested that stakeholder group should be evaluated according to attributes of power, urgency and legitimacy through questionnaires. They can score each other. Average, lower, and upper scores in the range of attributes of each group were defuzzified to be profile scores. The maximum profiles scores of power and urgency were belong to LAO, and of legitimacy was POLA while the minimum scores of those three attributes were occupied by Waste picker.

Phase 2: Stakeholder priorities and preferences

Profile scores of attributes of each stakeholder group were converted to be fuzzy linguistic classes. Combinations of these classes and Salience priority classes have corresponded to some rules in Table 1. Active rule(s) of each stakeholder group were agglomerated and defuzzified as examples of PNRE and Media showed in Figure 5.

Table 2: List of candidate stakeholders and their scores of management involvement

No.	Stakeholder groups	Abbreviation	Score	Percent	Representative
1	Local administrative	LAO	234.05	13.72	17
2	Provincial offices for natural resources and environment Phitsanulok	PNEP	227.48	13.33	3
3	Environmental office region 3	EOR3	217.89	12.77	3
4	Residential waste generators	RES_waste	186.92	10.96	13
5	Residents of nearby disposal site	RES_DS	158.92	9.31	9
6	Phitsanulok health provincial Office	Health	136.04	7.97	1
7	Community-based organizations	CO	122.12	7.16	6
8	Non-governmental organization	NGO	91.05	5.34	2
9	Private sector companies	Private	85.92	5.04	3
10	Province office for local administration	POLA	68.52	4.02	1
11	Academicians/ researcher	Academic	46.12	2.70	3
12	Waste picker/ scar venture	Waste picker	34.30	2.01	3
13	Volunteers Natural Resources and environment	Volunteer	33.04	1.94	1
14	4th Infantry division (Royal Thai Army)	RTA	29.00	1.70	1
15	Media	Media	23.42	1.37	2
16	Environmental consulting companies	Consulting	11.40	0.67	0
Total			1,706	100	68



(a) PNRE

(b) Media

Figure 5: Stakeholder analysis using Mamdani's FIS based on rules of Salience model

The defuzzified values represent preferences of stakeholder groups (Table 3). These processes were performed through the functions of Mamdani's FIS in Matlab software. From active rules, role characteristics and priority levels of stakeholders were immediately identified as summarized in Table 3. Their role characteristics can be described according to the definition of Mitchell et al., (1997). The groups with higher priority level have higher preferences or influence on decision making. High priority group was identified as definitive. It has the higher role to provide current input to the major decision and feedback processes. Medium and high priority groups of dependent and definitive require increased responsiveness from the organization toward their interests or views and/or gives an advice/information to other groups. Medium priority group of dependent plays roles of urgent claims and legitimate views but often rely on other stakeholders to carry out there to compensate due to lack of power to influence the organization.

Table 3: Summary of stakeholder role characteristics, priority levels, and preferences

No.	Stakeholders	Preference	Priority level	Role characteristic
1	EOR 3	2.54	High priority	Definitive
2	PNRE	2.54	High priority	Definitive
3	RTA	2.54	High priority	Definitive
4	CO	2.54	High priority	Definitive
5	LAO	2.54	High priority	Definitive
6	Health	2.54	High priority	Definitive
7	POLA	2.54	High priority	Definitive
8	RES_waste	2.32	Medium and high priority	Dependent and definitive
9	RES_DS	2.29	Medium and high priority	Dependent and definitive
10	Private sector	2.18	Medium and high priority	Dependent and definitive
11	Academic	2.09	Medium and high priority	Dependent and definitive
12	Media	1.98	Medium and high priority	Dependent and definitive
13	Volunteer	1.96	Medium and high priority	Dependent and definitive
14	NGOs	1.50	Medium priority	Dependent
15	Waste picker	0.45	Low priority	Discretionary

Low priority group of discretionary possesses legitimacy, but lack the power and urgent claim to influence the organization. Practically, selective stakeholder groups play crucial roles in different activities of MSW transportation management. For example, before NA is performed, some road segments of the input road dataset should be removed so that conflicts of interest on EI and VI can be reduced. The removal is advised by the groups of high priority level after screening information and suggestions from other groups of stakeholder. The same situation can be applied to disposal site constraint setup on its daily capacity and service activeness. To select an optimal waste transportation pattern in PROMETHEE outranking method, agreements from all stakeholder groups are legitimately required. They can express their privileges based on their preferences obtained from the stakeholder analysis. Their influences appear in stakeholder-criteria weights applied on winning scores of alternative comparison.

6. Conclusion

To achieve successful implementation of waste transportation management, the participation of stakeholders in decision making is strongly recommended and unavoidable. The study also proposed effective analyses of GIS and MCDA in the management. These analyses significantly require participation from stakeholder to reach the goal. The goal includes minimizing transportation cost, the environmental impact of sites, and vulnerability along optimum routes. As introduced herein, the removal of some road sections in the dataset before input into NA for optimum route extraction and privilege assignment for selecting optimal transportation pattern based on their preferences are evident as crucial roles of stakeholders. Stakeholder analysis for MSW management in local administrations of Phitsanulok province was performed as a case study. Fifteen relevant stakeholder groups, their opinions and preferences required for decision making in the management were obtained. The group with higher priority level has higher preference indicating more privilege on decision making. Seven stakeholder groups were identified as high priority (EOR 3, PNRE, RTA, CO, Admin, Local, and Health), 6 groups as medium and high priority (RES_DS, private sector, academic, RES_waste, media, and volunteer (Adhoc officer)), only one group of each medium and low priority which are NGO and Waste picker. The stakeholder identification process should be reassessed regularly for a certain period of management to ensure that no groups or individuals have been missed. This may involve identifying new stakeholders that need to be engaged and changing their priorities over the period (Durham et al., 2014).

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