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A System Dynamics View of Attitudinal Ambivalence on Solid Waste Management Service Provision

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Abstract. System dynamics (SD) approach is used to explain the influence of attitudinal ambivalence on SWM service performance through incentive based and knowledge based factors. According to that, a proposed SD model is constructed to present the holistic cause-and-effect relationships between and among solid waste management factors. This study also points out concerns that obstruct people from involving in waste minimization and separation. Problems and level of waste management service performance are also clarified.

Keywords: solid waste, waste management, system dynamics, human attitudes, service provision

1. Introduction

Solid waste (SW) has long been considered one of the most environmental concerns having socio-economic and environmental problems. The amount of generated MSW worldwide is expected to be 2.2 billion tons in 2025 [1]. With the conservative forecast, urban areas of Asia would generate 1.8 million tons a day of SW [2]. With this increasing level of SW generation, as a consequence of economic and urban growth, solid waste management (SWM) capability level of municipalities has long been lacked behind. Ineffective SWM system has become a fractured fabric of cities, refraining from having vibrant and sustainably growth.

Individual involvement is a vital factor for city development. However, level of involvement is attitudinal ambivalence. A number of studies have been conducted to identify influencing factors on such subjective issue, among many of them, incentive and knowledge related factors are of the potential ones [i.e. 3 – 4]. A great deal of research has involved software tools to design management systems, especially social systems including SWM ones [5]. Therefore, this study aims to apply a System Dynamics (SD) approach, as a software tool, to represent the influence of attitudinal ambivalence on SWM service performance. In details, the study objects to show cause-and-effect relationships of SWM influencing factors represented by a SD model. Moreover, the influence of incentive and knowledge related factors on SW attitudes of the people towards sustainable SWM system are identified. In this study Jatujak district of the city of Bangkok, Thailand is selected as a case study representing an urban area in a developing city that has witnessed ineffective SWM service provision.

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2. Literature Review

2.1. Municipal solid waste management in Bangkok

In Thailand, SW is defined as waste generated from community activities, residential households, commercial and business establishments, fresh markets, institutional facilities, and construction and demolition activities, but excludes industrial waste [6]. Jatujak district is one of 50 districts governed by the Bangkok Metropolitan Administration (BMA). As it is a district of the country's capital city, waste generation quantity (1st, 131,500 tons per year), population number (9th, 161,000 people), and total land areas (14th, 32.91 sq.km) of the district are in the top rank comparing to other districts. The district is the number one rank in terms of number of received appeals related to SWM problems, which is 1,513 cases, of these 599 cases are ineffective management related issues and the rest are ineffective staff [7]. The Department of Public Cleansing under the BMA and 50 district offices are responsible parties for city's hygiene, SWM, and the well-being of the residents. Kerbside collection is implemented as collection method. After SW is collected based on scheduled routes and time, it is transferred to three transfer stations. Sanitary landfill is the main treatment method, which is applied to about 90% of the total waste. The other 10% is managed by composting [6].

2.2. Human attitudes on municipal solid waste management

Human attitudes are subjective and are a matter of psychological tendency expressing by evaluation of a specific entity with different degree of favor or disfavor [8]. Like other social system studies, a close investigation is needed for understanding of human's intentions on behaviors on SWM [9]. Previous experiences from SWM service provision, both negative and positive, have high influence on people perceptions of performance of SWM. The perceptions are considered as human attitudinal ambivalence on SWM. Factors that affect human attitudes are habit, attitudes toward target, punishment or reward, social norms, and self-identified outcomes. SW generation amount is an important factor determining the effectiveness of SWM system. Thus, having accurate waste generation amount is the most important factor for effective system [10]. SW generation depends on waste generators' consumption styles, awareness, and attitudes on minimizing waste or separating waste before disposal. In this study, two groups of factors are addressed: incentive based related and knowledge based related factors. This is to find how these two groups of factors influence on waste minimization and waste separation at source attitudes of the people.

2.3. System dynamics

SD modelling was firstly coined by Forrester in 1960s as a special designed system analysis approach for dealing with linear and non-linear interactions, complex, and dynamic systems [11]. SD models can be used for assessing real situation, to study cause-and-effect interactions of different variables on the performance of a closed-loop chain [12]. Over time, SD applications have been prevalent in a wide array of disciplines, including SWM [i.e. 12 – 14]. SD models are constructed by using computer software. Variables are considered as system elements linked by mathematical mapping created by differential equations that are numerically solved via simulation. The models are represented by causal loop and stock flow diagrams, serving as foundation of how the studied system behaves. Represented in Fig. 1, each arrow in the diagrams links two variables and shows their relationships. Plus or minus signs represent effect of variables. If the effect and cause variable changes go in the same direction, a plus sign is given otherwise it will be a minus sign. When a complete loop is formed, a loop sign will be given. A balancing relationship sign (B) is given for the loop that has negative relationship. For a positive relationship loop, a reinforcing loop sign (R) is assigned. The sign can be in clockwise or counter-clockwise direction depending on directions of arrows.

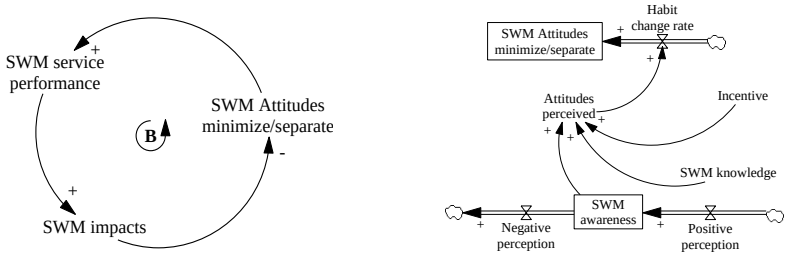

Fig. 1: Simple causal loop *(Left)* and stock flow diagrams *(Right)*.

A transformation of a causal loop diagram into a stock flow diagram is needed to enable a functional simulation. Stocks (symbolized by a rectangle) are system variables which values change over time. Flows (symbolized by a valve arrow) show the rate of change in stock variables and represent activities that fill in or flow out of the stocks. Auxiliary or constant variables are intermediate elements used for miscellaneous calculations. In the same way, connectors or arrows are used as information links between elements. To be able to simulate, all variables are linked by mathematical mapping created by differential equations that are numerically solved via simulation.

3. Methodology

3.1. Data collection

Questionnaire survey and face to face interview ($N = 422$) were the main methods of obtaining primary data. The survey was conducted during December 2013 to January 2014, and February to March 2015. The population frame for the survey was people (aged over 15) in Jatujak district, Bangkok, from communities, department stores, schools, universities, companies, temples, markets, hospitals and hotels. Random sampling method was applied. During the survey, respondents were interviewed regarding their attitudes on SWM service provision. There were 17 expert semi-structured interviews from various SWM related key stakeholders from government institutions, educational institutions, private companies, and NGOs. The interviewees were able to freely express their ideas on SWM regime, especially on influence of human attitudes on performance of SWM service. Literature review was a great source of fruitful information for this study. Sources of information were, for example, government databases, the World Bank and United Nations' databases, books, and published journal articles.

3.2. Data measurement and analysis

The questionnaire survey form consisted of four parts aiming to gain 1) demographic information; 2) general SWM information; 3) attitudes on SWM provided service; and 4) factors affecting SWM involvement. Experts were asked questions about current SWM service in Thailand, especially in Bangkok; influential factors that have impacts on the effectiveness of SWM system; and their ideas of human attitudes on SWM and waste minimization and source separation.

Analyzing quantitative data, the study employed the usefulness of computer programs to represent obtained data in a unified and understandable manner. Those programs were Vensim PLE version, which was used for formulating the SD model; and SPSS Statistics version 20 software package for analyzing obtained survey data. The collected data were transcribed and incorporated into the analysis, which was explained by using story and telling method. On the basis of accuracy and consistency, the collected secondary data were subsequently used to validate and complement to the study.

4. Results

4.1. Demographic and solid waste management information

The results show that there were 205 male and 217 female respondents. The majority of respondents had an average income of $US 300 to 600. Average household size was 3 people. For SWM at source, most of the respondents (96.7%) put waste in front of their houses or put in public bins. Each household generated 1 – 3 kilograms of waste per day. Only half of the residents (48.1%) paid for waste collection service fee with an average of $US 0.6 per month.

4.2. Attitudes on solid waste management service provision

About half of respondents (51.2%) conducted source separation on the economic purpose (selling recyclables as additional source of income). The respondents (55.9%) thought that the effectiveness of their provided SWM service was in moderate level as they had experienced many problems: odor smell from waste (68.5%), uncollected waste (51.2%), not on time collection (39.1%), fallen waste during transporting (31.8%), and no SWM service (7.6%). The respondents (87.2%) thought that everyone in the city should be part of SWM system. Most of the respondents (88.8%), would like to take part in source separation and minimize waste generation through 3Rs. However, there were some concerns as they would not be able to do

the activities: sorting waste is complicated (69.3%); do not have time (65.3%); and no proper trash bins (78.5%). In terms of SWM awareness, respondents thought that waste generation should be reduced (91.7%); waste should be effectively managed (89.3%); waste causes environmental problems (88.6%); waste is a source of alternative energy (66.9%); and waste causes socio-economic impacts (64.9%).

4.3. Influential factors on attitudinal ambivalence

As previously stated that 88.8% of respondents would like to take part in SWM by doing source separation and minimization, when it comes to a real situation, it is very difficult to know that those people will actually do such activities. Therefore, this study addressed influential factors that affect human attitudes on waste minimization and separation. Those factors were classified into two groups: 1) incentive based (i.e. cash, vouchers, discount coupons, and goods) and 2) knowledge based (i.e. types of recyclables, importance of effective SWM system, public benefits, and environmental education). The experts were asked to fill in values of how likely they would conduct the activities if incentive and/or knowledge were provided. Those values were presented in a form of an equation; given that: 'a' is changed attitude values; 'm' is given incentive; and 'k' is provided knowledge.

$$a = 0.003m^2 + 0.208m + 0.002k^2 + 0.311k + 1.939$$

4.4. System dynamics model

After reviewing all essential variables that are needed for modelling a SD model, Fig. 2 demonstrates the interrelationships of SWM system when incentive and SWM knowledge factors are applied. It can be seen from the model that these two factors have reinforcing impacts on '*Attitudes perceived*', then '*Habit change rate*' is affected by '*Attitudes perceived*', which further has influence on other elements of the model in cause-and-effect flow.

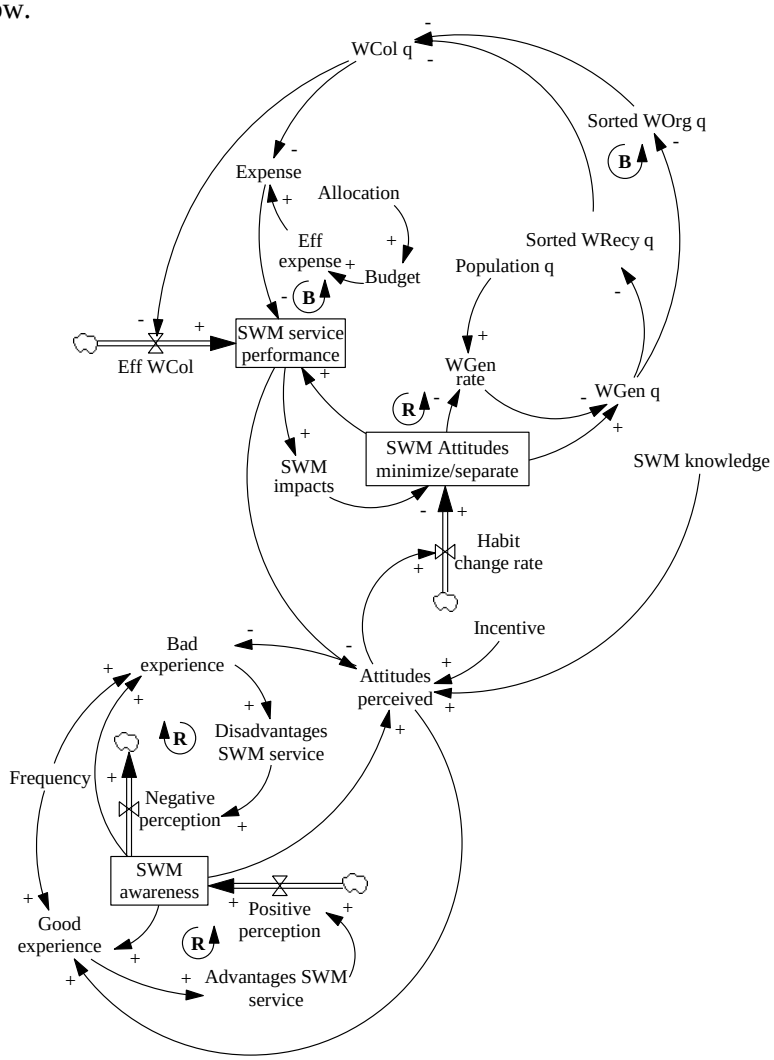

Fig. 2: System dynamics model of attitudinal ambivalence on solid waste management service provision.

5. Conclusion

A SD modelling approach was used to represent the influence of attitudinal ambivalence on SWM service performance. The study explains overall situations of SWM service performance and SWM awareness of the people. Concern points that refrain the people from minimizing waste and separating waste are identified. The proposed SD model presents cause-effect relationships of SWM factors showing the reinforcing impacts of the influence of incentive and knowledge related factors on SW attitudes of the people towards sustainable SWM system.

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