Exploring the implementation barriers of eco-toilet system in the Philippines using Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach

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Abstract. Eco-Toilet system (ETS) is an emerging sanitation technology that promotes water conservation and nutrient recovery. Although many kinds of literature support the promising benefits of ETS, the implementation of such technology in the Philippines still faces a myriad of challenges. The study found out that the implementation of ETS in the country was affected by the following barriers: (a) policy and institutional capacity/commitment, (b) investment/financial issues, (c) technology and operation viability, and (d) social acceptance. DEMATEL was used as an analytical framework to investigate these key barriers. This method utilized the value judgments of experts and converted this information into quantitative data. Several computations were applied to reveal the causal relationships and prominence of the implementation barriers of ETS in the Philippines. Therefore, this study can benefit decision-makers in addressing implementation issues involving ETS projects in the country.

Keywords: Sustainable Development; Ecological Sanitation; DEMATEL

1. Introduction

Human excreta contains pollutants such as pathogenic microorganisms and biological nutrients (i.e., nitrogen and phosphorus) which can pose serious threats to public health and the environment when not properly treated and disposed of (1,2). In addition, a significant influx of nutrients from toilet effluents can cause irreversible environmental damages to the aquatic system, i.e., eutrophication (3). Therefore, it is imperative to apply proper sanitation management system to mitigate the adverse impacts of improper human excreta disposal.

However, in the Philippines, using a septic tank as a sanitation management system, remains to be the conventional sanitation method used by most households (4). Since toilets connected to septic tanks require ample amount of freshwater to flush down toilet wastes, those communities who do not have access to water usually opt to practice open defecation which may inevitably lead to contamination of food and water sources (5).

Given these water and sanitation issues, implementation of an environmental sanitation technology such as Eco-Toilet System (ETS), a water-less toilet, is regarded as a major effort aimed to manage human excreta in consonance with the circular economy notion and the sixth Sustainable Development Goal (SDG 6) (6). Through the ETS, feces and urine are collected separately and kept undiluted through a urine diversion process (7) then they undergo aerobic composting and urine hygienization, respectively. This process allows for the removal of pathogens and the safe recovery of organic solids and nutrients and the resulting by-products can then be used as soil conditioner and liquid fertilizer.

However, these benefits do not come without hindrances. In fact, the environmental sanitation technology that was introduced to the Philippines in the early 2000s became unsuccessful. Failure of the
project was seen to have rooted mostly from the lack of experience and knowledge of the project developers on implementing such an unconventional sanitation model (8). However, the implementation of the technology in the succeeding years provided significant technical and experiential contributions to the policy making process and passing of environmental laws in the country, such as the integration of ecological sanitation in the Philippines’ Clean Water Act of 2005, and the formation of legislative reform – Ecological Sanitation Act of 2007 (9,10).

Further, studies relating to ETS (or similar models) were also able to identify barriers that may have hampered the successful implementation of ETS (5,7,9,11). Barriers were seen such as those relating to a strong political framework, financial capability and accountability on the part of the users, technical issues relating to design and operation of the ETS, and behavioral intention to use ETS as a sanitation facility, thus, a comprehensive evaluation of these barriers must be carried out if it is to be implemented in a country such as the Philippines.

In view of the above, this study aims to explore the potential key implementation barriers of ETS in the Philippines. This study proposes that the initial approach to ETS implementation should include an analysis of the implementation barriers in order to predict and prioritize potential issues that can critically affect the project. This study further explores the application of Decision Making Trial and Evaluation Laboratory (DEMATEL) technique as an analytical tool to determine the causal relationships and prominence of the barriers to the implementation of ETS in the Philippines. Although DEMATEL has already been used such as in the studies of Promentilla et al (12) and Kumar and Dixit (13), there are only a few studies that utilized such a tool for analyzing an environmental technology such as ETS.

The results of this study can be used to develop strategies for policy development and implementation of ETS, particularly in developing countries, such as the Philippines.

2. Methodology

2.1 Theoretical framework: DEMATEL

DEMATEL is a mathematical framework that is based on graph theory (14). This tool was developed by the Science and Human Affairs Center in Battelle Memorial Institute of Geneva and has been used by the global science community to analyze causal interdependence and relationship among study variables for solving complex multi-criteria decision-making problems. Unlike other MCDM models such as AHP, DEMATEL categorizes the variables into cause and effect groups based on their respective scores in the analysis. The level of importance (or prominence) of each variable can also be identified using this method.

There are several steps involved in analyzing DEMATEL data. These are the following computational steps:

2.1.1 Defining the measurement scale. DEMATEL utilizes human’s rationality to weigh potential influences between any variables (i.e., variable i and variable j; where variable i ≠ variable j). These influences can be weighed using a linguistic influence rating scale such as that of Promentilla et al (12), where each influence rating value indicates the strength of influence of any variable i to any variable j. This measurement scale is applied in the DEMATEL survey questionnaire of this study. When rating any paired variables, a respondent can assign any integer number within the range of 0 – 4: where 0 = no influence, 1 = very low influence, 2 = low influence, 3 = high influence, and 4 = very high influence. Each response of any respondent p will generate a pairwise rating which is denoted by $a_{ij}^p$.

2.1.2 Construct the initial direct relation matrix $Z$. Every completed DEMATEL survey ratings of any respondent p will generate a non-negative $n \times n$ matrix, $Z^p$, also mathematically expressed as in equation (1).

$$Z^p = \begin{bmatrix} a_{11}^p & \cdots & a_{1n}^p \\ \vdots & \ddots & \vdots \\ a_{n1}^p & \cdots & a_{nn}^p \end{bmatrix} = [Z_{ij}^p]$$

where $n =$ total number of variables.
Thus, the \( m \) number of DEMATEL survey respondents will generate \( Z_1, Z_2, Z_3, \ldots, Z_m \) non-negative matrices. The aggregated score of all the respondents is calculated using Equation (2). This equation forms the initial direct relation matrix \( Z_{ij} \):

\[
Z = \frac{1}{m} \sum_{p=1}^{m} Z_{ij}^p
\]

where \( 1 \leq p \leq m; i, j \in \{1, 2, \ldots, n\} \).

2.1.3 Normalize initial direct relation matrix. The initial direct relation matrix is then normalized using Equation (3). Hence, a normalized direct relation matrix \( D \) is formed.

\[
D = k \cdot Z
\]

where \( k = \min \left( \frac{1}{\max_{i,j} \sum_{j=1}^{n} |a_{ij}|}, \frac{1}{\max_{i,j} \sum_{i=1}^{n} |a_{ij}|} \right); i, j \in \{1, 2, \ldots, n\} \).

In this equation, \( \max_{i,j} \sum_{j=1}^{n} |a_{ij}| \) represents the total direct effect of the variable with the strongest direct effects to the other variables. On the other hand, \( \max_{i,j} \sum_{i=1}^{n} |a_{ij}| \) indicates the strongest total direct effects that any variable \( j \) received from other variables.

2.1.4 Calculate and construct the total relation matrix. After acquiring the normalized direct relation matrix \( D \), the direct and indirect effects of all variables \( i \) to all variables \( j \) are computed. The combination of these effects is called the total effects. The computation can be carried out by applying the Markov chain theory, as in Equation (4). All \( D \) matrices raised to any number greater than 0 and 1 represent the indirect effects between the variables. This equation also indicates that the indirect effects diminish as the power of \( D \) increases, which guarantees convergent solutions to matrix inversion:

\[
T = D + D^2 + \ldots + D^k = D (I - D)^{-1} = \begin{bmatrix}
    t_{11} & \cdots & t_{1n} \\
    \vdots & \ddots & \vdots \\
    t_{n1} & \cdots & t_{nn}
\end{bmatrix} = [t_{ij}]_{n \times n}, \ i, j \{1, 2, \ldots, n\}
\]

where \( I \) is identity matrix; \( n \times n \) is null matrix.

2.1.5 Assign threshold \( \alpha \)-cut value and eliminate variables. A threshold \( \alpha \)-cut value is then assigned to filter the minor effects between variables. The threshold \( \alpha \)-cut value can be based on the experts’ preference, a literature review, or the median score of the values in the total relation matrix \( T \). In this study, the threshold \( \alpha \)-cut value considered is the median score of the total effects. A similar approach was carried out by Promentilla et al. (12).

All \( t_{ij} \) values greater than \( \alpha \) are retained in the analysis. In contrast, all \( t_{ij} < \alpha \) values are nullified, in other words, converted to zero. Hypothetically, the \( t_{ij} < \alpha \) values have no significant influence to the entire cluster and, thus, elimination of these values are necessary. After the elimination, the retained values form the final total relation matrix \( (\alpha\text{-cut}) T_{\alpha} \). Further, removing the minor effects provides less complexity to the presentation of the causal diagram or impact relation map (IRM).

2.1.6 Compute and identify the prominence and relations. The \( r \) and \( c \) values are used to identify the prominence and relations. These values can be obtained from the matrix \( T_{\alpha} \), where \( r \) represents the sum of the rows and \( c \) represents the sum of the columns of \( T_{\alpha} \). These can be mathematically represented as in Equations (5) and (6), respectively.

\[
r = \sum_{j=1}^{n} t_{ij}
\]

\[
c = \sum_{j=1}^{n} t_{ij}
\]

In this equation, every \( r \) value represents the total effects of each variable \( i \) to other variables \( j \) (where \( j = 1, 2, \ldots, n \)). While \( c \) values represent the total effect received by variable \( j \) from other variables \( i \) (where \( i = 1, 2, \ldots, n \)).
Henceforth, the sum of $r_i$ and $c_j$ can be computed, given that $i = j$. The $(r_i + c_j)$ values are called “prominence”, which indicates the index of the strength of influence [or the degree of importance] of variable $i$. Thus, the variable with the highest prominence value is the most important variable in the system.

On the other hand, the difference between $r_i$ and $c_j$ depicts the net effect that variable $i$ contributes to the entire problem structure. These $(r_i - c_j)$ values are called the “relation”. Arithmetically, if $r_i < c_j$, the difference will be a negative value. This means that the total effects received by a variable are greater than the total effects that it gives to the other variables. Thus, all negative $(r_i - c_j)$ values are considered as the net receiver or “effect” variable. In opposite, if $r_i > c_j$, the difference will be a positive value. This indicates that the impact of the total effects of the variable is stronger than the total effects that it receives. Therefore, this variable is regarded as the net causer or “cause” variable.

2.1.7 Obtain impact-relation map (IRM). Once all the $(r_i + c_j)$ and $(r_i - c_j)$ values are acquired, IRM can be plotted. Let the $(r_i + c_j)$ values be the $x$ coordinates and $(r_i - c_j)$ values be the $y$ coordinates. This will be the final output of this DEMATEL study.

2.2 Proposed evaluation framework

In this study, DEMATEL was carried out using several procedures that were described in Figure 1.

2.2.2 Identification of ETS Implementation Barriers. This study conducted a literature review to identify the important ETS implementation barriers. Initially, fifteen (15) sub-barriers were listed which were categorized into four (4) main barriers namely: policy and institutional capacity/commitment, investment/financial issues, technology and operation viability, and social acceptance. However, after an expert’s evaluation, only 12 sub-barriers were retained and utilized in the study. The final list of barriers with their respective sub-barriers were presented in Table 1.

| Table 1. Main barriers and sub-barriers in implementing an Eco-Toilet System (ETS) |
| --- |
| **Barrier** | **Sub-barrier** |
| P | Policy and institutional capacity/commitment |
| P1 | Lack of LGU awareness and political will for improving sanitation |
| P2 | Lack of policies, effective governance, and regulation regarding the onsite human excreta treatment and use of ETS by-products |
| P3 | Poor enforcement of policies |
| I | Investment/financial issues |
| I1 | Lack of financial capacity to pay for the initial capital requirements, operation, and maintenance |
| I2 | Lack of willingness to pay |
| I3 | Users require additional monetary incentives and operational services |
| I4 | Lack of sense of ownership, responsibility, and accountability |
| T | Technological and operational viability |
| T1 | Poor design and construction |
| T2 | Insufficient awareness-raising and user training |
| T3 | Lack of convenient end-product management and utilization system (handling and usage of excreta fertilizer) |
| T4 | Improper usage and maintenance |
| S | Social acceptance |
| S1 | Behavioral intention to use ETS |
2.2.3 Model construction and problem identification. Figure 2 provided the visualization of the hierarchical structure of the identified decision-making problem. For this study, the contextual relationships between the sub-barriers (level 3) and their level of importance (or prominence) were the main interest since these were the indicators of each of the main barrier. Each sub-barrier was compared to other sub-barriers found in the same barrier as well as to the sub-barriers of other barriers.

![Figure 2. Hierarchical decision-making structure of barriers to ETS implementation](image)

2.2.4 Development of Survey Questionnaire. The survey questionnaire contained 132 DEMATEL questions that were related to the rate of influence between sub-barriers. The questionnaire was divided into 14 sections: (a) cover letter and consent, (b) demographic questionnaire, (c) DEMATEL questionnaire for each of the 12 sub-barriers with adequate instructions or guide.

2.2.5 Data Collection. The knowledge of the experts on ETS implementation was utilized to improve the understanding of the causal relationships and prominence of ETS implementation barriers. The experts considered were those who had an experience in implementing an ETS or similar models, and were knowledgeable to the current challenges of ETS implementation in the Philippines. Hence, this study reached out to three (3) relevant experts from an academic institution who were involved in an ETS-related research project. Such a sample size could be fairly considered in the analysis since MCDM models such as DEMATEL were not statistically-based and could utilize a small sample size of no less than 3 samples. The experts were given a structured questionnaire and were asked to indicate their perceived strength of influence of each sub-barrier to another sub-barrier.

3. Results and Discussion

The DEMATEL method was used to interpret the responses of the experts. The responses were computed using Microsoft Excel. All numerical values were rounded-off to 3-decimal places.

3.1 Computation of impact-relation matrices

Each completed questionnaire generated a $12 \times 12$ direct relation matrix by applying Equation (1). The aggregated responses of the experts populated the average direct relation matrix $Z$, as shown in Table 2. This result represented the average pairwise evaluation scores given by the three experts on the strength of influences between the sub-barriers which was obtained using Equation (2). Subsequently, the average direct relation matrix $Z$ was normalized using Equation (3). The new formed matrix is shown on Table 3 and is now known as the normalized direct relation matrix $D$.

### Table 3. Direct relation matrix, $Z$

|       | P1    | P2    | P3      | H     | I2    | I3         | I4     | T1     | T2     | T3     | T4     | S1      |
|-------|-------|-------|---------|-------|-------|------------|--------|--------|--------|--------|--------|---------|
| P1    | 0.000 | 3.667 | 3.667   | 1.667 | 1.667 | 1.333      | 1.333  | 0.333  | 2.333  | 1.000  | 1.333  | 2.667   |
| P2    | 3.000 | 0.000 | 3.000   | 1.000 | 0.667 | 1.000      | 1.333  | 1.000  | 2.667  | 1.667  | 1.000  | 3.000   |
| P3    | 2.333 | 3.333 | 0.000   | 1.000 | 0.667 | 1.333      | 2.000  | 0.667  | 2.000  | 2.333  | 1.667  | 3.000   |
values populated the final total relation matrix called the total relation matrix (alpha-cut) in influence to
The total relation matrix \( T \) is then computed using Equation (4). The result is presented on Table 4. Each \( t_{ij} \) value on each row (horizontal direction) represents the total influence that each sub-barrier \( j \) was contributing to each respective sub-barrier \( i \) while \( t_{ij} \) values on each column (vertical direction) is the value of influence that the sub-barrier \( j \) is receiving from sub-barrier \( i \), e.g., \( P1 \) is giving 0.331 influence to \( P2 \), \( P1 \) is receiving 0.304 from \( P2 \) (refer to values on Table 4).

The minor effects were then filtered by applying a threshold value. In this study, the threshold value assigned was the median score of all the values on the total relation matrix \( T \), which was 0.251. All values that were not able to meet the \( \alpha \)-cut (threshold value) were converted to null or zero. The retained values populated the final total relation matrix called the total relation matrix (alpha-cut) \( T_\alpha \), as seen on Table 5.

\[
\begin{array}{cccccccccc}
\text{Table 4. Normalized direct relation matrix, } & D & & & & & & & & \\
\hline
P1 & P2 & P3 & P4 & P5 & P6 & P7 & P8 & P9 & P10 \\
\hline
P1 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
P2 & 0.10 & 0.10 & 0.06 & 0.06 & 0.06 & 0.06 & 0.06 & 0.06 & 0.06 & 0.06 \\
P3 & 0.03 & 0.03 & 0.03 & 0.03 & 0.03 & 0.03 & 0.03 & 0.03 & 0.03 & 0.03 \\
P4 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 & 0.01 \\
P5 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
P6 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
P7 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
P8 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
P9 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
P10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
\end{array}
\]

\[
\begin{array}{cccccccccc}
\text{Table 5. Total relation matrix, } & T & & & & & & & & \\
\hline
P1 & P2 & P3 & P4 & P5 & P6 & P7 & P8 & P9 & P10 \\
\hline
P1 & 0.20 & 0.21 & 0.22 & 0.23 & 0.24 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 \\
P2 & 0.21 & 0.22 & 0.23 & 0.24 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 \\
P3 & 0.22 & 0.23 & 0.24 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 \\
P4 & 0.23 & 0.24 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 \\
P5 & 0.24 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 \\
P6 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 \\
P7 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 \\
P8 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 \\
P9 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 \\
P10 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 & 0.38 \\
\end{array}
\]

\[
\begin{array}{cccccccccc}
\text{Table 6. Total relation matrix (alpha-cut), } & T_\alpha & & & & & & & & \\
\hline
P1 & P2 & P3 & P4 & P5 & P6 & P7 & P8 & P9 & P10 \\
\hline
P1 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 & 0.38 & 0.39 & 0.40 & 0.41 & 0.42 \\
P2 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 & 0.38 & 0.39 & 0.40 & 0.41 \\
P3 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 & 0.38 & 0.39 & 0.40 \\
P4 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 & 0.38 & 0.39 \\
P5 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 & 0.38 \\
P6 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 & 0.37 \\
P7 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 & 0.36 \\
P8 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 & 0.35 \\
P9 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 & 0.34 \\
P10 & 0.24 & 0.25 & 0.26 & 0.27 & 0.28 & 0.29 & 0.30 & 0.31 & 0.32 & 0.33 \\
\end{array}
\]
Table 6 shows the relations (cause and effects) and prominence of the sub-barriers. The $r$ and $c$ values were computed using Equations (5) and (6). The cause and effect variables were identified by calculating the difference between the $r$ and $c$ values. Each sub-barrier was identified as a cause or an effect variable depending on its $r - c$ value. Sub-barriers with $r - c > 0$, or have positive values, were considered as the cause variables, else sub-barriers with $r - c < 0$, or negative values, were regarded as effect variables. Table 6 arranged the order of the cause and effects variables, from highest to lowest. In addition, to determine the level of importance (or prominence) of each sub-barrier, the $r + c$ values were considered.

Table 7. Summary of results of the DEMATEL analysis

| Indicators | $r$  | $c$  | $r - c$ | $r + c$ |
|------------|------|------|---------|---------|
| Cause      |      |      |         |         |
| T2 (Insufficient awareness-raising and user training) | 3.252 | 0.787 | +2.465 |         |
| T1 (Lack of financial capacity to pay for the initial capital requirements, operation, and maintenance) | 1.980 | 0.739 | +1.241 |         |
| T3 (Lack of convenient end-product management and utilization system (handling and usage of excreta fertilizer)) | 1.776 | 0.549 | +1.227 |         |
| T1 (Poor design and construction) | 1.317 | 0.275 | +1.042 |         |
| I3 (Additional monetary incentives and operational services required by users) | 2.462 | 1.618 | +0.844 |         |
| Effect     |      |      |         |         |
| P3 (Poor enforcement of policies) | 1.510 | 3.110 | -1.601 |         |
| T4 (Improper usage and maintenance) | 0.256 | 1.530 | -1.275 |         |
| T1 (Lack of willingness to pay) | 1.543 | 2.630 | -1.087 |         |
| P2 (Lack of policies, effective governance, and regulation regarding the onsite human excreta treatment and use of ETS by-products) | 1.269 | 2.126 | -0.857 |         |
| P1 (Lack of LGU awareness and political will for improving sanitation) | 1.883 | 2.699 | -0.816 |         |
| S1 (Behavioral intention to use ETS) | 4.059 | 4.854 | -0.796 |         |
| I4 (Lack of sense of ownership, responsibility, and accountability) | 2.331 | 2.721 | -0.390 |         |
| Prominence |      |      |         |         |
| S1 (Behavioral intention to use ETS) | 8.913 |      |         |         |
| I4 (Lack of sense of ownership, responsibility, and accountability) | 5.053 |      |         |         |
| P3 (Poor enforcement of policies) | 4.620 |      |         |         |
| P1 (Lack of LGU awareness and political will for improving sanitation) | 4.582 |      |         |         |
| I2 (Lack of willingness to pay) | 4.173 |      |         |         |
| I3 (Users require additional monetary incentives and operational services) | 4.081 |      |         |         |
| T2 (Insufficient awareness-raising and user training) | 4.038 |      |         |         |
| P2 (Lack of policies, effective governance, and regulation regarding the onsite human excreta treatment and use of ETS by-products) | 3.395 |      |         |         |
| T1 (Lack of financial capacity to pay for the initial capital requirements, operation, and maintenance) | 2.720 |      |         |         |
| T3 (Lack of convenient end-product management and utilization system (handling and usage of excreta fertilizer)) | 2.325 |      |         |         |
| T4 (Improper usage and maintenance) | 1.786 |      |         |         |
| T1 (Poor design and construction) | 1.593 |      |         |         |

Based on the calculations, there were five (5) sub-barriers categorized as cause variables. The sub-barriers were: “Insufficient awareness-raising and user training (T2)”, “Lack of financial capacity to pay for the initial capital requirements, operation, and maintenance (T1)”, “Lack of convenient end-product management and utilization system (handling and usage of excreta fertilizer) (T3)”, “Poor design and construction (T1)”, and “Additional monetary incentives and operational services required by users (I3)”. These sub-barriers were the net cause drivers which tend to cause certain net impacts to the sub-barriers. In other words, the net impacts that these sub-barriers gave greater impacts than the net impact that they received. The result indicated that the sub-barrier “Insufficient awareness-raising and user training (T2)”, which has the highest positive $r - c$ value, was the most dominant causal barrier among
the sub-barriers. This implies that programs that promote awareness and proper usage of the ETS is very vital in implementing eco-toilet systems in the Philippines. The study of Fruh (9) in 2003 agreed that public awareness and promotion of proper usage (reuse of human excreta) were necessary to boost the marketability of the ETS and its byproducts in the Philippines. Similar findings were also found in the studies of Cordova and Knuth (15) and Davies-Colley and Smith (16).

On the other hand, having $r - c < 0$, the remaining sub-barriers were classified as effect variables. These include: “Poor enforcement of policies (P3)”, “Improper usage and maintenance (T4)”, “Lack of willingness to pay (I2)”, “Lack of policies, effective governance, and regulation regarding the onsite human excreta treatment and use of ETS by-products (P2)”, “Lack of LGU awareness and political will for improving sanitation (P1)”, “Behavioral intention to use ETS (S1)”, and “Lack of sense of ownership, responsibility, and accountability (I4)”. These barriers were more likely to receive the impacts from the causal variables. Among these sub-barriers, the “Poor enforcement of policies (P3)” was found to be the most easily affected sub-barriers. The least affected sub-barrier was the “Lack of sense of ownership, responsibility, and accountability (I4)”.

Table 6 also arranged the level of importance (or prominence) of each sub-barrier. According to the results, “Behavioral intention to use ETS (S1)”, “Lack of sense of ownership, responsibility, and accountability (I4)”, and “Poor enforcement of policies (P3)” were the top three (3) most important sub-barriers with $r + c$ values of 8.913, 5.053, and 4.620, respectively. “Poor design and construction (T1)”, “Improper usage and maintenance (T4)”, and “Lack of convenient end-product management and utilization system (handling and usage of excreta fertilizer) (T3)” were the three (3) least important sub-barriers with $r + c$ values of 1.593, 1.386, and 2.325, respectively. This could possibly indicate that the design and construction, usage and maintenance, and end-product management and utilization system of ETS in the Philippines were already adequate. That is why, based on this empirical evidence, these sub-barriers were the least priority. However, the three sub-barriers with the highest prominence values could indicate that these sub-barriers, especially “Behavioral intention to use (S1)” of the users, would require the greatest attention when implementing an eco-toilet system in the Philippines. Therefore, in the context of the Philippines, it is recommended that the behavioral intention of the users should be addressed first.

3.2 Impact-relation map (IRM)

Finally, this DEMATEL study provided an IRM (figure 3), which was an enhanced illustration of the results found in table 5 and 6. In figure 3, the prominence ($r + c$) and relations ($r - c$) of the sub-barriers were plotted on the x and y axes, respectively. The sub-barriers that were closest to zero in the x-axis, such as T4, T1, and T3, were the least important and had the weakest correlation in the system. In contrast, the sub-barrier with the highest x value such as S1 was the most important and had the strongest correlation. A solid double arrow was used to indicate that the both sub-barriers had bi-directional relationship (correlation) or effects and a broke line arrow for uni-directional relationship. On the other hand, the y-axis arranged the sub-barriers into two groups. Sub-barriers that were located on the positive vertical axis belonged to the cause group and those on the negative vertical axis were those of the effect group. Sub-barriers with higher y values had stronger impact compared to those with the lower y values. Hence, T2 could be interpreted as the most dominant causal sub-barrier and P3 as the most impacted effect sub-barrier.

Since the IRM already provides a schematic view of the flow of relationships between implementation barriers and sub-barriers, it then helps the project developers, policy makers and other implementing stakeholders, to have a clearer point of view as to which among the identified barriers and sub-barriers are related to or affecting which barrier or sub-barrier. Further, IRM also plays a significant role in helping stakeholders organize and suggest future actions in overcoming barriers that could hamper the ETS implementation to a community who has been using a conventional sanitation method, such as the Philippines, since it can also serve as their strategy map that may help them anticipate and address ETS implementation issues so as to minimize, if not totally avoid, waste of resources later on.
4. Conclusion
This study demonstrated the application of DEMATEL for evaluating the barriers to the implementation of Eco-Toilet System in the Philippines. The current study utilized sub-barriers that were selected from related literatures. The results from the DEMATEL analysis revealed the causal relationships that described the interrelationships of the sub-barriers as well as their level of importance (or prominence) in the decision-making. The empirical evidence can help ETS project developers and policy makers in identifying and prioritizing potential issues and developing strategies from hereon.

According to the experts, “insufficient awareness-raising and user training” had the highest net impact to other sub-barriers in the system. These findings implied that policymakers and project developers need to concentrate on activities that could promote awareness and users-training when implementing ETS in the Philippines. Apparently, although ETS was not a new technology in the Philippines, the knowledge of the Filipinos regarding its concept, usage, and benefits remained unpopular in many communities. Thus, addressing this gap should stimulate solutions to problems that may be encountered during project implementation. Conversely, “poor enforcement of the policies” was found to be the least influential sub-barrier; hence, should be allocated the least resources.

Lastly, the empirical result of this study suggests that the current and future implementation of ETS in the Philippines should allocate greater attention to the three most critical sub-barriers which are “Behavioral intention to use ETS (S1)”, “Lack of sense of ownership, responsibility, and accountability (I4)”, and “Poor enforcement of policies (P3)”. Based from the interrelationship between each sub-barrier, the result could mean that the sub-barrier was critical because the combination of its net impact and net effect was observed to be very robust in the system. In addition, the sub-barriers with the highest prominence scores indicated a high correlation among the other sub-barriers.

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