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Index Risk of Sanitation (IRS) Modelling to Determine Domestic Waste Water System

Florianus Rooslan Edy Santosa[1], Arief Dwi Atmoko[2], Sri Wiwoho Mudjanarko[1*]

[1]Program Study of Civil Engineering, Engineering Faculty
Narotama University, Surabaya, INDONESIA

[2]Program Study of Law, Faculty of Law,
Narotama University, Surabaya, INDONESIA

*Corresponding Author

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Abstract: 100% Clean water access and feasible sanitation are aims that mentioned within National Medium-Term Development Plan 2015-2019. The present study aims to create sanitation modelling to determine waste water management system and its sustainability. The present study shows two discriminant equations which are: 1) discriminant 1 : Z1 = -41.863 - (1.156*IRS) + (0,066*PM) + (0,160*PP) + (0,111*PWM), and discriminant 2 : Z2 = 6.743 + (1.542*IRS) + (0,014*PM) + (0,207*PP) - (0,256*PWM). Both discriminants are used to determine domestic waste water system; 2) Z1 = -4.011 + (1.246*PMS) + (3.699*KEU) + (1.164*KLM). This discriminant is used to determine the sustainability status in which a sub-district can be regarded as success (1) or failed (2). Variables that are used in determining waste water system are Index Risk Sanitation (IRS) Female Participation (PP), Poor People as Beneficiary (PWM), and Beneficiaries (PM). Meanwhile variables that influencing the sustainability status are Society Participation (PMS), Financial (KEU), and Regulation/Institutional (REG). First equation in form of Territorial Map and when it is applied into 154 sub-districts in Surabaya it shows result as follow: 1) Based on index risk sanitation: there are 9 sub-districts or 5,84% included as less risk area, 70 sub-districts or 45,451% included as medium risk area, 55 sub-districts or 35,71% included as high risk area, and 20 sub-districts or 12,99% included as very high risk area; 2) Based on Domestic Waste Water System: there are 57 sub-districts (37,01%) categorised in Domestic Communal System, 31 sub-districts (20,13%) categorised in Domestic IPAL Tube Sys-tem, and 66 sub-districts (42,86%) categorised in combination of communal and IPAL systems; and 3) Based on Sustain-ability Status of Domestic Waste Water System: there are 120 sub-districts (77,92%) regarded as success group dan 34 sub-districts (22,08%) regarded as failed group.

Keywords: Index Risk Sanitation, Discriminant Equation, Domestic Waste Water System, Sustainability

*Corresponding author: sri.wiwoho@narotama.ac.id

1. Introduction

One of the goals of *Millenium Development Goals* (MDGs) is concerning 50% improvement of clean water and sanitation based on total number of people that are not receiving those facilities. In order to achieve the goals, Indonesian government establishes *National Action Plan* in which one of the aims is focusing on sanitation sector (Pemerintah Provinsi Jawa Timur, 2015). Within *National Action Plan* it is mentioned that the target of national sanitation access is around 89,35% for urban area and 62,94% for suburb area. Development of sanitation in Indonesia has been prioritised by regional and national government in which it can be seen from National Medium-Term Development Plan (RPJMN). In regional level, target of *Millenium Development Goals* has been revised into *Universal Access 2019* mainly in sanitation sector. Moreover, it has been proclaimed by most of regional heads into Regional Work Plan.

Based on work plan program and activities of Department of Public Work and Administration in East Java related to development budget of 2015, improvement of clean water and decent sanitation are fundamental rights for the society. Therefore, fulfilment of clean water and decent sanitation for citizen who live in urban and suburb area shall be improved to achieve high healthy living standard.

Based on statistical data published by East Java Statistics Bureau No. 50/07/35/Th. XII, 18 July 2014, until 2013 East Java province able to increase the proportion of household in developing sustainable decent sanitation up to 59,80% in which national target for this sector is around 62,41% until 2015. Therefore, generally East Java province optimist in achieving the target of MDGs in 2015. Proportion indicator of household concerning sustainable decent sanitation until 2013 can be seen in Fig. 1.

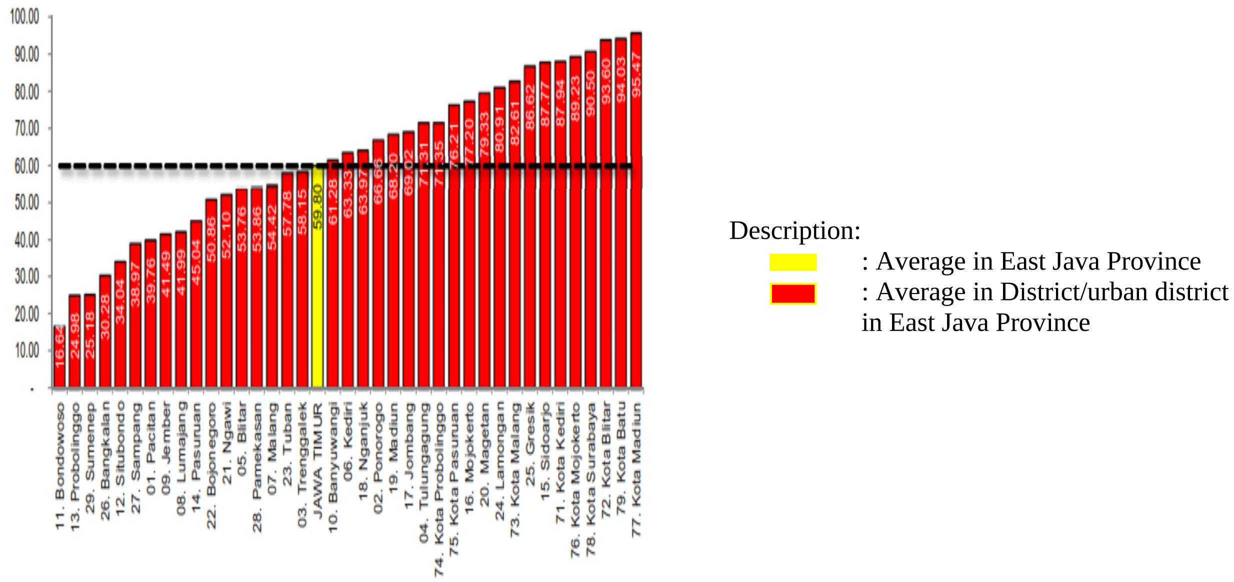


Fig. 1 - Proportion of household in district/urban district in East Java Province in 2013 toward decent access of sanitation.

East Java province through Department of Public Work and Administration needs fund around 2.3 billion rupiahs to improve waste water service from 72,15% in 2013 into 73,40% in p 2015. Index Risk Sanitation modelling in the present study aims to achieve *Universal Access 2019* target. Moreover, the present study aims to determine portray risk level of sanitation risk in which it can be used as reference in determining domestic waste water system.

2. Research Background

Multiple process in managing waste water into healthy result or final process is known as sanitation (Mara et al., 2010). Significance development of sanitation able to increase numerous aspects of living for instance health, social, and economics mainly in developing country. In developing country like Indonesia, there are various sanitation issues such as the area (urban or suburb), clean water supply, disposal of fecal matter, and waste water disposal (Carter, 1999). The people behaviour in disposing waste water is determined by the household and regulation imposed by government (Mara & Alabaster, 2008). Domestic waste water that are produced by people will be processed in multiple process in order to gain additional value. Although at the end of the process it will be disposed into final disposal place (Pembangunan sanitasi, 2010). Domestic waste water using central system consists of waste water collecting system, processing, and final disposal in large debit (Massaoud et al., 2009). Based on construction aspect, central system is commonly used in small settlement in urban district. Moreover, it is used by low and middle class people (West, 2001; Parkinson et al., 2003).

About health risk area in Surabaya explained that: 18% regarded as high risk area, 22% regarded as medium risk area, 45% regarded as low risk area, and 14% regarded as clear area (Santosa & Hermana, 2012). Further study shows health environmental area in Surabaya as follow: there are 9 sub-district or 5,48% included as less risk area (index 1), 67 sub-districts or 43,51% included as medium risk area (Index 2), 61 sub-districts or 39,61% included as high risk area (index 3), and 17 sub-districts or 11,04% included as very high risk area (index 4) (Santosa, 2016). Very high risk area according to Santosa means slum area in coastal, downstream river, and territorials water with high population density. Meanwhile, less risk area is an area which arranged properly and it has low population density.

3. Research Methodology

3.1 Field Study

Field study is conducted in numerous processes such as analyzing primary data in form of Index Risk Sanitation (IRS), analyzing secondary data (Population density, Clean water access, Access to latrine, and number of poor people), Field trip and Perception of Group Work toward Sanitation in Surabaya, also assessment of Urban Sanitation and Rural Infrastructure (USRI) program in 2012-2015 concerning domestic waste water and its sustainability.

3.2 Mapping of Index Risk Sanitation (IRS)

Various steps that taken in order to get IRS mapping in Surabaya are as follow: divide village into 4 classes (score 1, 2, 3 and 4). Determination of the present classes is based on addition of numerous value which are: IRS, secondary data analysis, field trip result, and group work perception toward sanitation in Surabaya

3.3 Index Risk Sanitation (IRS) Mapping Result

IRS mapping results of Surabaya are: Less Risk Area (score 1) 9 sub-districts or 5,84%, Medium Risk Area (score 2) 70 sub-districts or 45,45%, High Risk Area (score 3) 55 sub-districts or 35,71%, and very high risk area (score 4) 20 sub-districts or 12,99%.

3.4 Determination of Domestic Waste Water

Result of IRS is in form of risk area map toward health living condition in Surabaya. The map consists of 154 (one hundred fifty five) sub-districts in which 41 (forty one) sub-districts are used as sample to determine domestic waste water system through Urban Sanitation and Rural Infra-structure (USRI) program. Index Risk Sanitation (IRS) Modelling to Determine Domestic Waste Water System.

3.4 Analyzing IRS of Surabaya in form of map with 4 (four) classes

Classification result is used as reference to determine Domestic Waste Water System which are:

i. Communal Latrine, IPAL Communal
ii. Combination of Communal Latrine and IPAL Communal.
iii. Analysing relation between IRS and Domestic Waste Water System coupled with its sustainability status by utilising discriminant analysis.
iv. Formulating relation between IRS and Domestic Waste Water System, IRS and the sustainability status, in which the result will be used as reference model.

4. Results and Discussion

4.1 The Connection Between Index Risk of Sanitation (IRS) and Domestic Wastewater System

The relationship between the index risk of sanitation (IRS) and domestic wastewater systems can be described in Table 1 and Fig. 2. Table 1 describes the cross tabulation of urban villages for the IRS and Domestic Wastewater System (DWS). It can be seen from 41 urban villages, most of those villages are in the Medium Risk (Score 2) classification which applied the combination of communal Wastewater Treatment Plant (IPAL) and communal waste system as the wastewater system.

Fig. 2 explains that all urban villages with less risk status (score 1) apply the Domestic Wastewater System (DWS) which combined the communal Wastewater Treatment Plant (IPAL) and communal waste system. Meanwhile, for the urban villages that scored Medium Risk status (Score 2) are using the Domestic Wastewater System (DWS) which combined with the communal Wastewater Treatment Plant (IPAL) and communal waste system. Ur-ban villages that scored High Risk status (Score 3) and Very High Risk status (Score 4) applied variations of the three Domestic Wastewater Systems.

The High Risk urban villages (Score 3), with a composition of 27.3%, 36.4%, and 36.4% respectively are communal waste system, communal waste system with piping, and a combination of communal Wastewater Treatment Plant (IPAL) and communal waste system. Moreover, the urban villages with Very High Risk status (Score 4) or 84.6% applied the communal waste system option, 7.7% applied the communal wastewater treatment plant (IPAL) with piping, and the remaining 7.7% applied the Domestic Wastewater System (DWS) which combined between the communal Wastewater Treatment Plant (IPAL) and communal waste system. For the urban villages with medium and less risk, 100% households use Domestic Wastewater System (DWS) with a combination of Communal Wastewater Treatment Plant (IPAL) and communal wastewater system.

Table 1 - Cross Tabulation Between the Index Risk Sanitation (IRS) and the Domestic Wastewater System.

Supporting Factors for Sustainability Criteria		Index Risk Sanitation Code (SRI)			Total
		Communal Wastewater System	**Communal Wastewater Treatment Plant (IPAL) with Piping**	**Communal Wastewater Treatment Plant and Communal Waste System**	
Index Risk Sanitation Code (IRS)	**Less Risk (Score 1)**	0	0	1	1
	Medium Risk (Score 2)	0	0	16	16
	High Risk (Score 3)	3	4	4	11
	Very High Risk (Score 4)	11	1	1	13
Total		14	5	22	41

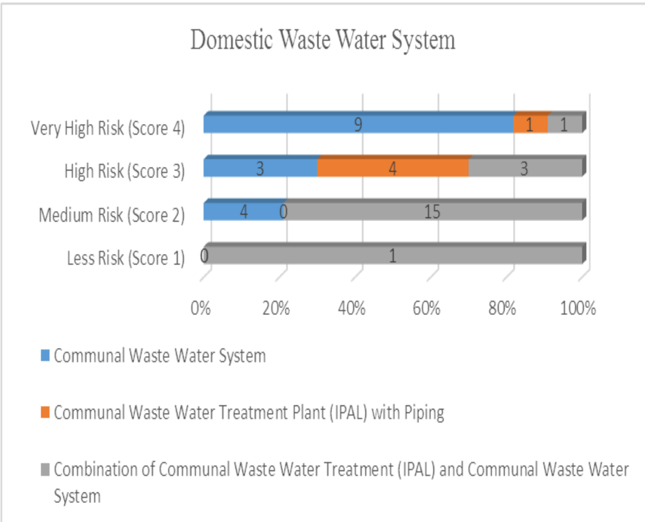


Fig. 2 - Percentage between Index Risk Sanitation (IRS) and Domestic Wastewater System.

4.2 The Connection between Domestic Wastewater Systems and The Number of Sustainability Criteria

Domestic Wastewater System and the Number of Sustain-ability Criteria of an urban village has a less significant relationship. This can be seen in Table 2 which shows the diversity of relationships between the Domestic Wastewater System and the Number of Sustainability Criteria. It can be seen that out of 22 villages that have used the Domestic Wastewater System (DWS) with a combination of Communal Wastewater Treatment Plant (IPAL) and communal waste system, there are 3 urban villages that only have 1 Sustainability Criteria variable, 2 urban villages have 2 -

Sustainability Criteria variables, 10 urban villages have 3 Sustainability Criteria variables, 6 urban villages have 4 Sustainability Criteria variables, and 1 urban village have 5 variables Sustainability Criteria. In which from the 5 urban villages that use the communal Wastewater Treatment Plant (IPAL) using piping there are 1 urban village that only has 1 Sustainability Criteria variable, 2 urban villages have 2 Sustainability Criteria variables, 1 urban village has 3 Sustainability Criteria variables, and 1 urban village has 4 Sustainability Criteria . Meanwhile, 14 urban villages that use the communal wastewater system, there are 5 urban villages having 2 Sustainability Criteria variables, 3 urban villages have 3 Sustainability Criteria variables, 4 urban villages have 4 Sustainability Criteria variables, and 2 urban villages have 5 Sustainability Criteria variables.

Table 2 - Cross Tabulation Between Domestic Wastewater Systems and the Number of Sustainability Criteria.

		Sustainability Criteria: Total Score					Total
		1	2	3	4	5	
Domestic Wastewater System Code	Communal Wastewater System	0	5	3	4	2	14
	Communal Wastewater Treatment Plant (IPAL) with Piping	1	2	1	1	0	5
	Combination of Communal Wastewater Treatment Plant (IPAL) and Communal Waste System	3	2	10	6	1	22
Total		4	9	14	11	3	41

It also can be seen in Fig. 3, the urban villages that use the combination of Domestic Wastewater System, wastewater treatment plant (IPAL), communal waste sys-tem, Communal wastewater treatment plant with piping coupled with Communal wastewater system have diversity in the number of Sustainability Criteria variables. Most urban villages that use combination system of the Communal wastewater treatment plant (IPAL) and communal waste system have 3 sustainability criteria variables (45.5%). Meanwhile, most urban villages that use the communal wastewater treatment plant (IPAL) with Piping have 2 sustainability criteria variables (40.0%), and most of the urban villages that are using the communal waste system have 2 sustainability criteria variables (35.7%). Therefore, it can be concluded there are connection be-tween the Domestic Wastewater System and the number of Sustainability Criteria variables.

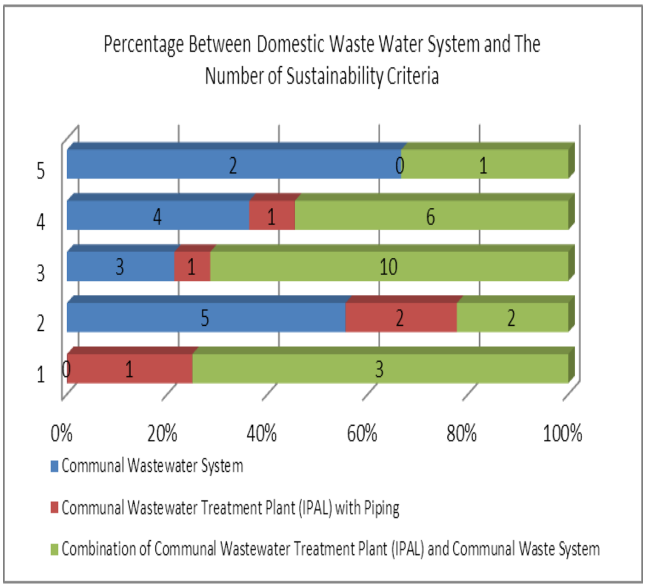


Fig. 3 - Percentage Between Domestic Wastewater Systems and the Number of Sustainability Criteria.

4.3 Discriminant Analysis to Determine Domestic Waste Water System

Discriminant analysis to determine domestic waste water is conducted to choose variables that fit into model or to determine independent variables that are influencing Domes-tic Waste Water System. Analysis result of discriminant can be seen on Table 3.

Table 3 - Cross Tabulation Between Domestic Wastewater Systems and the Number of Sustainability Criteria.

Supporting Factors of Sustainability Criteria	Wilks' Lambda	F	df1	df2	Sig.
Index Risk Sanitation (IRS)	0,321	39,11	2	37	0
River Flow Area	0,940	1,18	2	37	0,31
Population Density	0,975	0,47	2	37	0,62
Business Area	0,978	0,42	2	37	0,65
Beneficiaries	0,096	175,17	2	37	0
Women Participation	0,083	204,5	2	37	0
Poor People Receiver	0,094	179,10	2	37	0
Cost Analysis	0,984	0,301	2	37	0,74

Table 3 shows from 8 independent variables there are 4 variables that significantly different: index risk sanitation, beneficiaries, women participation, and poor people receiver in which sig value of those variables are 0,000 (less than 0.05). It means determination of domestic waste water system consists of 3 options which are: 1 (Communal La-trine), 2 (IPAL with tubes), and 3 (combination between IPAL and communal latrine). Variables that are chosen to determine discriminant function 1 and 2 has been determined therefore the next step will be forming discriminant function based on 4 variables that have strong correlation. Coefficient for each discriminant function can be seen on the table 4 mentioned below.

Table 4 - Cross Tabulation Between Domestic Wastewater Systems and the Number of Sustainability Criteria.

Supporting Factors of Sustainability Criteria:	Function	
	1	2
Domestic Waste Water Code System	-1,156	1,542
Beneficiaries	0,066	0,014
Women Participation	0,16	0,207
Poor people receiver	0,111	-0,256
(Constant)	-41,863	6,743

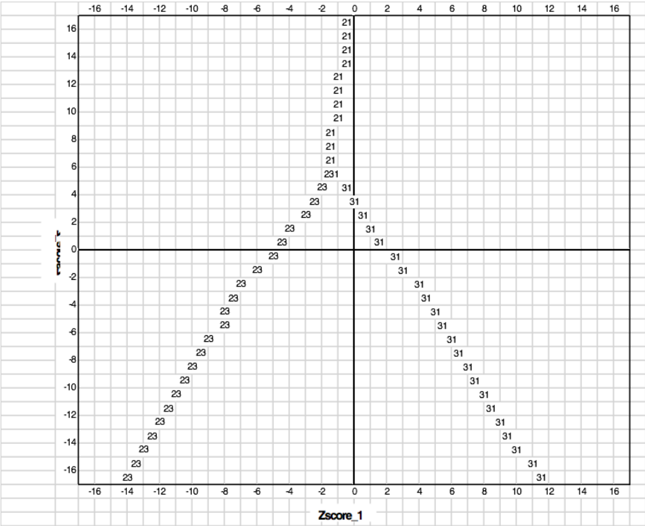
Unstandardized coefficients

IRS states value of index risk sanitation, PM means beneficiaries, PP means women participation, and PWM means poor people receiver each sub-district, therefore discriminant equation will be as follow: **Discriminant Function 1**: Z1 = -41.863 - (1,156*IRS) + (0,066*PM) + (0,160*PP) + (0,111*PWM) and **Discriminant Function 2**: Z2 = 6.743 + (1,542*IRS) + (0,014*PM) + (0,207*PP) - (0,256*PWM).

In order to gain effectivity in determining data placement toward certain group *Territorial Map* can be utilized. *Territorial Map* has function to map limits in each code based on axis X (discriminant function 1) and axis Y (discriminant function 2). Furthermore, this map able to portray coordinate of sub-district which can be used to determine the *territory* (Domestic Waste Water System).

4.4 Territorial Map

Canonical Discriminant Function 2



Canonical Discriminant Function 1

Symbols used in territorial map		
Symbol	**Group**	**Label**
1	1	Communal latrine
2	2	IPALwith Tubes
3	3	Combination between Communal latrine and IPAL with tubes

* Indicates a group centroid

Fig. 4 - Territorial Map of Domestic Waste Water System.

When the Territorial Map is applied to 154 sub-districts in Surabaya the result will be as follow: 60 sub districts (39%) regarded as Domestic Waste Water System using Communal Latrine, 30 sub-districts (19%) regarded as IPAL with tubes waste water system, and 64sub-districts (42%) regarded as combination between communal and IPAL. Map of Surabaya Domestic Waste Water System can be seen on Fig. 5 below.

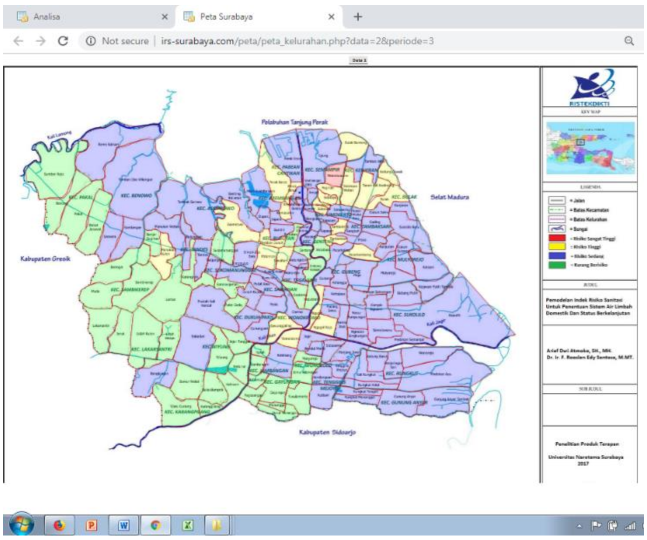


Fig. 5 - Map of Surabaya Domestic Waste Water System.

4.5 Discriminant Analysis for Sustainability Status

Discriminant analysis to monitor sustainability status uses stepwise method in order to select the variables that are included in the model. Below are the results of stepwise independent variables that influence the sustainability status grouping. Table 5 illustrates the results of testing 5 independent variables in Sustainability Status group. It shows that according to 5 independent variables, there are 3 variables were significantly different which are: Community Participation, Finance, and Institution-al/Regulatory, where each value Sig. are respectively 0.060, 0.000, and 0.000 (less than 0.05). It means that the Sustainability Status is influenced by several variables which are Public Participation, Finance, and Institutional / regulation in a village. In other words, fruitfulness or failure of domestic waste water -

system is affected by public participation within this system, the existence of public expenses concerning implementation and maintenance of domestic wastewater system, and the absence of Institution-al/Regulatory domestic wastewater system in the village.

Table 5 - Testing Results of Each Variable in Sustainability Status Grouping.

Sustainability Criteria	Wilks' Lambda	F	df1	df2	Sig.
Physical Building	.a				
Wastewater Quality Test	0,98	0,813	1	39	0,373
Community Participation	0,822	8,447	1	39	0,006
Finance	0,305	88,78	1	39	0
Institutional/ Regulatory	0,703	16,488	1	39	0

a. Cannot be computed because this variable is constant

It is determined in the present research that code FIN means financial variable, CP means community participation variable, and REG means institutional/regulation variable therefore the discriminant equations that are obtained as follows: Z1 = -4011 + (1246*CP) + (3699*FIN) + (1164*REG). To determine Sustainability Status Group prediction, in which a village can be included into Success Group (1) or Fail (2). This prediction is achieved by com-paring the results of discriminant scores (from the calculation of the value of Z score) with a limit value (cut-off score). The cut off score (the limit value) is made by looking at Table 6 concerning the composition of the members of Status Sustainability Group, it appears that there are 28 villages which can be included as success meanwhile there are 13 villages which can be included as failed. It can be seen further in Table 7 by using centroid group numbers.

Table 6 - The composition of Group Members Sustainability Status.

Sustainability Criteria: Criterial code for Success/ Failure	Prior	Cases Used in Analysis	
		Unweighted	weighted
Success	0,5	28	28
Failure	0,5	13	13
Total	1	41	41

Table 7 - Centroid Group to Group Sustainability Status.

Sustainability Criteria: Criterial code for Success/ Failure	Function
	1
Success	1.288
Failure	-2.774

Unstandardized canonical discriminant functions evaluated at group means

Then the value of the critical figures is calculated and stated by using Zcu also it will be served as the cut off score as written below:

$$Zcu = \frac{(N_S \times Z_G) + (N_G \times Z_S)}{N_S + N_G}$$

Where in:

- Zcu = critical number, which serves as a cut-off score.
- N_S = The number of samples in Group Success
- N_G = The number of samples in Group Failure
- Z_S = The number of centroid in Group Success
- Z_G = The number of centroid in Group Failure

Result:

$$Zcu = \frac{(28 \times -2.774) + (13 \times 1.288)}{28 + 13} = \frac{-60.928}{41} =$$

Usage figures Zcu:

- If the figure score a village above Zcu then included in the Group Success.
- If the figure score a village under Zcu then included in the Group Failure.

Based on sustainability progress of domestic waste water system it can be said that there are 120 districts (78%) can be regarded as successful group in maintaining the sustain-ability and 34 districts (22%) are regarded as failed group in maintaining the sustainability. The map of sustainability progress of domestic waste water system can be seen in the Fig. 6.

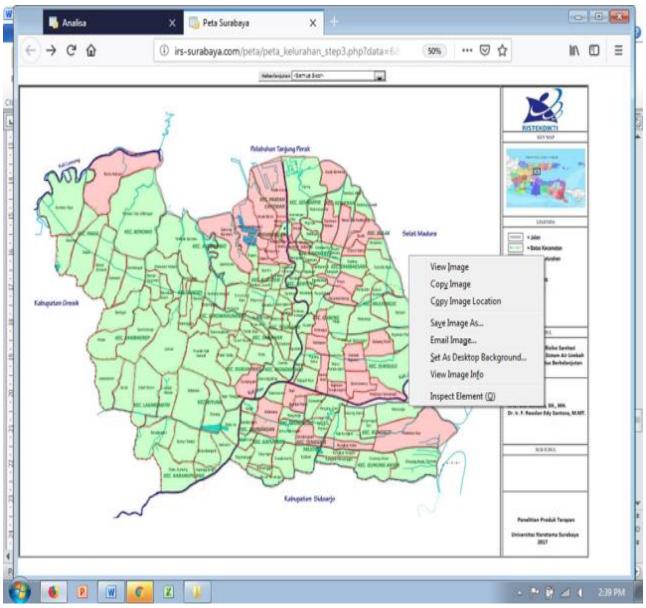


Fig. 6 - The Map of Sustainability Progress of Domestic Waste Water System in Surabaya

5. Summary

According to result of the present study, it can be concluded that:

1. The present study generates two discriminant equations, in which the first equation in form of Territorial Map that is used to determine domestic waste water system. The second equation is used to determine sustainability of domestic waste water system. There are numerous variables which play role in determining domestic waste water system such as Sanitation Risk Index (IRS) the number of female as participants, Poor Citizen as Receiver coupled with Beneficial Receiver. Meanwhile, variables that play role in determining the sustainability progress of domestic waste water system are Society Participation, Financial, and Institutional/Regulation.

2. *Territorial Map* shows Z1 and Z2 in which Z1 is discriminant function 1 (axis X) and Z2 is discriminant function 2 (axis Y). The result is Z1 and Z2 where Z1 is the discriminant function 1 (X axis), and Z2 is the discriminant function 2 (Y axis). Axis X and Y are absent and ordinate from Territorial Map.
3. When *Territorial Map* is applied toward 154 districts in Surabaya, the classifications that can be seen are:
    a) There are 9 districts or 5,84% which can be regarded as less risk area (index score 1), 70 districts or 45,451% can be regarded as medium risk area (index score 2), 55 districts or 35,71% can be - regarded as high risk area (index score 3) and 20 districts or 12,99% can be regarded as very high risk area (index score 4).
    b) 60 districts (39%) are included into domestic waste water system for common toilet's (MCK) group, 30 districts (19%) can be included in the group of waste water treatment plant (IPAL) with plumbing system, and 64 districts (42%) can be included in the group of combination between domestic waste water system for common toilet and waste water treatment plant (IPAL) with plumbing system.
    c) There are 120 districts (78%) which can be regarded as successful group in maintaining the sustainability and 34 districts (22%) are regarded as failed group in maintaining the sustainability.

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