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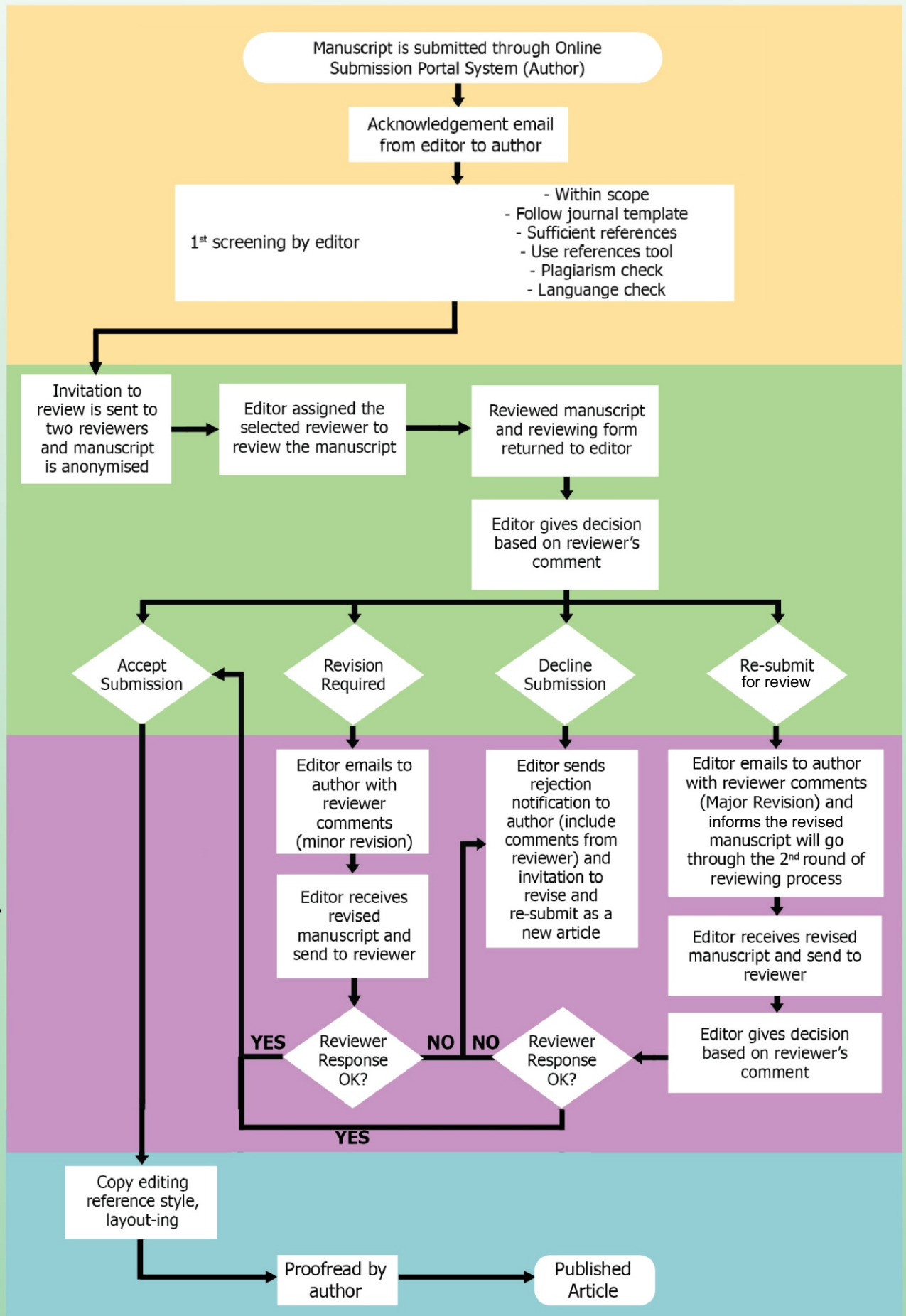
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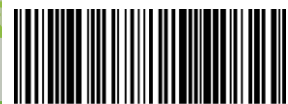


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Determination of Risk Areas in the Cimahi City (Drainage Sector) Based on City Sanitation Strategy Guidelines

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ABSTRACT Cimahi is one of the cities which participated in the Accelerated Habitat Sanitation Development Program in 2011 due to its poor sanitation conditions. The city experienced high flooding in 2018 as observed in the 36.4 hectares or approximately 0.76% of the total area affected even though its drainage system was discovered to be covering 89.87% in 2015. There are also several reports of displacement of residents and significant financial loss in the city due to flooding in the past decade and this means urgent attention needs to be provided to improve the condition of the city. Therefore, this study was conducted to calculate the level of risk from the drainage sector in each urban village of Cimahi City. This involves using scores ranging from 1 – 4, with a score of 1 indicating very low risk while 4 represents very high risk based on exposure factors such as percentage of inundation area, sanitation risk index (IRS) score, and the opinions of local government as well as impact factors such as population, population density, poverty rate, and urban/rural function. The research made use of both primary and secondary data with the primary data obtained through interviews with the population in the study area and local government representatives while secondary data were obtained from different institutions. The results showed 7 out of the 16 urban villages in Cimahi City are in Risk Category 1, 5 in Category 2, 1 in Category 3, and the remaining 2 in Category 4. This information with the risk category map for each village is expected to be used by the local government of Cimahi to analyze the flood-related problems better and create more effective solutions.

KEYWORDS Drainage; Risk Score; Exposure Factors; Impact Factors; Risk Areas.

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1 INTRODUCTION

The recent growth, development, and increase in population density in many areas of Indonesia including Cimahi City have increased the pressure on space and the environment and this is evident in the need for housing, industrial/service areas, and supporting facilities which have led to the transformation of open land and/or wetlands into built-up areas (Iwan Juwana, Muttill, & Perera, 2014, I. Juwana, B. Perera, & N. Muttill, 2009, Noor & Pratiwi, 2016, Nursidika, Sugihartina, Susanto, & Agustina, 2018, Sutiarani & Rahmafitria, 2016). This further has severe impacts on the capacity of urban drainage and flood control facilities and infrastructures such as rivers, reservoirs, flood pumps, and regulating

gates to drain water to its final destination, which is usually the sea (Imrona, Budiutama, Darwiyanto, & Handayani, 2019, Wijaya & Permana, 2017).

Cimahi is one of the cities that participated in the 2011 Sanitation Settlement Development Acceleration Program (Samyahardja, 2019; Triningtyas & Putri, 2019) based on the poor sanitation conditions as observed by the Cimahi City Government (Bahari, Kastolani, Waluya, & Geografi, 2016; Herdianti, Gemala, & Erfina, 2019) which are particularly drainage-related as evident with the occurrence of flood in several areas of the city. According to the drainage master plan released by the Local Planning

Agency (OPD), there are 36 floods spots and 2 floods areas in the Cimahi Tengah sub-district alone which are mainly caused by the poor condition of drainage infrastructure and public sanitation attitudes. These have, however, led to infrastructural damage, economic loss, and a decrease in community health in the last decade (Fauziah, Putu, Sukmono, & Karnisah, 2018; Nandi, 2018; Wisata, Wardhani, & Sulistyowati, 2019).

This, therefore, shows the need to develop an appropriate sanitation strategy for Cimahi City and this led to the conduct of the study to determine the risk areas related to the management of drainage system in order to have the adequate information in formulating the strategy (Fionita & Juwana, 2019; Yasya & Juwana, 2019).

2 METHODS

This study was conducted using both primary and secondary data. The primary data were mainly on the sanitation risk index of the community and opinion of local governments which were obtained through questionnaires while secondary data including the maps of the area, existing flood spots, population, population density, and poverty rate were retrieved from the documents provided by government institutions.

The research was conducted using the following steps:

1. Determination of Weights for Exposure and Impact

The importance of exposure and impact factors is not equal, and this means there is a need to assign certain weights for each of them and their subsequent parameters. The exposure factor has 3 parameters which are the percentage of inundation area, IRS score, and OPD perception while impact factor has 4 which are the population, population density, poverty rate, and urban/rural function. An Analytical Hierarchy Process (AHP) was, however, used due to its consideration as the

most suitable method in this context (Diana & Utari, 2019).

A pairwise comparison was conducted for each parameter of both exposure and impact factors to determine the weight. The rating for the exposure factor is as follows:

- Total population takes precedence over population density.
- Total population takes precedence over poverty rate.
- The population is preferred over the urban/rural function.
- Population density takes precedence over poverty rates.
- Population density takes precedence over urban/rural functions.
- The poverty rate takes precedence over urban/rural function.

The rating for the impact factors are as follows:

- Percentage of pool area takes precedence over IRS.
- Percentage area of inundation takes precedence over OPD perception.
- IRS takes precedence over OPD perception.

2. Determination of Exposure Score

The exposure score was calculated by aggregating the values for the inundation area, IRS score, and OPD perception after the weights have been obtained (Fionita & Juwana, 2019; Sunik, Kristianto, & Khamelda, 2018; Yasya & Juwana, 2019). These values were normalized using a computer-based application provided by the National Development Planning of Indonesia (BAPPENAS) with the value for the parameters obtained as follow:

a. Percentage Area of Inundation

The value for each urban village in the studied area was calculated using the following Equation (1) (Yasya & Juwana, 2019).

$$\%inundation\ area = \frac{Inundation\ Area\ per\ Urban\ Village}{Administrative\ Area\ per\ Urban\ Village} \quad (1)$$

b. IRS Score Based on EHRA

This was calculated using the following steps:

- Stratification of Urban Village
The samples were selected through stratified random sampling method based on certain population differences (de Oliveira Arieira, Santiago, Franchini, & de Fátima Guimarães, 2016; Jing, Tian, & Huang, 2015; Shields, Teferra, Hapij, & Daddazio, 2015) including population density, poverty rates, areas drained by rivers, and areas affected by flooding.

- Determination of the Number of Family as Samples

A certain number of families were selected as samples through the use of the Slovin formula presented in the following Equation (2).

$$n = \frac{N}{1 + N \times e^2} \quad (2)$$

Where n is the number of samples, N is the number of family in Cimahi City while e is an error of 10%

- Determination of Number of Respondents
The number of respondents for each urban village was also obtained based on the stratified sampling method. This involved multiplying the number of family and percentage of urban villages per stratum as shown in Equation (3).

$$NR1 = n \times \%R \quad (3)$$

Where $NR1$ is the number of respondents in stratum 1, n is the number of family card samples, and $\%R$ is the percentage of urban village per stratum.

- Determination of Dangerous Sources
From each question, 1 - 2 answers were selected to determine the level of danger and weight to be used in calculating the risk index.

For example, the following question was included in the questionnaire.

Q1: Is there a waste disposal facility apart from feces disposal in your house?

- A : (a). Yes, there is.
(b). No, there is not.

- Weighting

The weight for each question is determined based on its level of risk to the drainage (I Juwana, Muttill, & Perera, 2016a, 2016b; I. Juwana, Muttill, & Perera, 2012; I Juwana, Perera, & Muttill, 2010; I. Juwana, B. J. C. Perera, & N. Muttill, 2009). For example, the previous sample question is weighted 20% due to its possible strong effects on the final IRS score.

- Environmental Risk Index Score (IRS)

This was calculated after the information has been obtained from the respondents using Equations (4) and (5).

$$\%Q1 = \frac{\text{number of respondents that selected a particular}}{\text{total of respondents}} \times 100\% \quad (4)$$

$$nQ1 = \text{weight} \times \%Q1 \quad (5)$$

Where $\%Q1$ is the percentage of respondents that selected a particular answer from question number 1 ($Q1$) while $nQ1$ is the risk index score for $Q1$ after which the final risk index score was calculated by aggregating the risk index scores for all the questions.

- c. Relevant Local Institution (Organisasi Perangkat Daerah, known as OPD) Perception

This was a risk assessment conducted based on the experience or expertise of OPD members on the drainage component in Cimahi City. This study made use of 5 OPDs to provide perceptions for drainage risk scores and the values were obtained as an average of the overall perception score provided.

The values from the parameters were later converted to a score between 1-4 as shown in

the following Equations (6) to (9) (Yasya & Juwana, 2019).

$$X > X_{min} + 75\% \cdot (X_{max} - X_{min}) \rightarrow 4 \rightarrow \text{very high risk} \quad (6)$$

$$X > X_{min} + 50\% \cdot (X_{max} - X_{min}) \rightarrow 3 \rightarrow \text{high risk} \quad (7)$$

$$X > X_{min} + 25\% \cdot (X_{max} - X_{min}) \rightarrow 2 \rightarrow \text{low risk} \quad (8)$$

$$X > X_{min} + 0\% \cdot (X_{max} - X_{min}) \rightarrow 1 \rightarrow \text{very low risk} \quad (9)$$

Where x is value per parameter, X_{min} is the smallest value in every urban village, and X_{max} is the largest value in every urban village.

The exposure scores were calculated using Equation (10) after the values have been obtained (Yasya & Juwana, 2019).

$$\text{Exposure Score} = (E1 \times B1) + (E2 \times B2) + (E3 \times B3) \quad (10)$$

Where $E1$ is the score of percentage inundation area, $B1$ is the weight percentage of inundation area, $E2$ is the IRS score, $B2$ is the IRS score weights, $E3$ is the OPD perception score, and $B3$ is the weight perception of OPD.

3. Determination of Impact Score

The 4 parameters used in determining the impact score include population, population density, poverty rate, and urban/rural function.

a. Population

The population was calculated by dividing the total population of the village with the number of residents in the city using the following Equation (11).

$$\text{Population} = \frac{\text{urban village population}}{\text{city population}} \times 100\% \quad (11)$$

b. Population density

The population density value was calculated by dividing the total population

by the built area in person/Ha as described in Equation (12).

$$\text{Population density} = \frac{\text{population}}{\text{wide built area}} \times 100\% \quad (12)$$

c. Poverty rate

The poverty rate was calculated by dividing the number of poor households and the total number of households using Equation (13).

$$\text{Poverty rate} = \frac{\text{population of poor family card}}{\text{total family card}} \times 100\% \quad (13)$$

d. Urban/Rural Function

The urban/rural function in each district was based on the Central Bureau of Statistics with value 1 applied for rural and 2 for urban function.

All the scores were later converted to a score of 1-4 using Equations (6) to (9) after which the impact score was calculated with Equation (14).

$$\text{Impact score} = (E4 \times B4) + (E5 \times B5) + (E6 \times B6) + (E7 \times B7) \quad (14)$$

Where $E4$ is population score, $B4$ is population weight, $E5$ is population density score, $B5$ is population density weight, $E6$ is poverty rate score, $B6$ is poverty rate weight, $E7$ is urban/rural function score, and $B7$ is urban/rural function weight.

4. Drainage Risk Score Calculation and Mapping

The drainage risk scores were calculated using the following Equation (15) after the exposure and impact scores have been determined (Yasya & Juwana, 2019).

$$\text{Drainage Risk Score} = \text{Exposure Score} \times \text{Impact Score} \quad (15)$$

The final drainage scores obtained for each urban village were plotted in a map to provide better visualization of the risk. The red color on the map represents a score value of 4 or the highest risk, yellow for 3, green for 2, and blue for 1 which is the lowest risk.

3 RESULTS AND DISCUSSION

3.1 Weighting of Exposure and Impact Scores

The weights assigned to each parameter of exposure and impact factors are shown in Table 1 and 2.

Table 1. Exposure Parameters' Weight

Parameter	Weights
Percentage of Inundation	70%
IRS Score	24%
OPD Perception	6%

Source: Calculation Results, 2019

Table 2. Impact Parameters' Weight

Parameter	Weights
Population	44%
Population Density	32%
Poverty Rate	17%
Urban/Rural Function	7%

3.2 Exposure Score Determination

The three parameters used in determining the exposure score were the percentage of inundation area, IRS score, and OPD perception and later converted into the range 1-4.

a. Percentage of Inundation Area

This was calculated by dividing the inundation area with the administrative area (Perdani & Yusuf, 2016; Sitorus, Ashri, & Panuju, 2016) and the risk scores obtained are presented in Table 3.

b. IRS Score

The different levels in each urban village were determined using four main criteria including population density, poverty rates, areas drained by rivers, and areas affected by flooding and no urban village was found to be in levels 0 and 1 while six including

Pasirkaliki, Citeureup, Cipageran, Baros, Leuwigajah, and Cibeber were in level 2, six others including Cibabat, Karangmekar, Setiamanah, Padasuka, Cimahi, and Melong in level 3, and three including Central Cigugur, Cibeureum, and Utama were in level 4.

Slovin formula with an error rate of 10% showed 100 families were to be surveyed after the level or strata for each village has been identified.

c. OPD Perception

The OPD's perception was obtained from the interviews conducted with the head and staff in the city drainage section of the Department of Housing and Settlement and the scores were calculated based on an average of 5 (five) scores provided by the head and staff with the results shown in Table 3.

The exposure scores were calculated by multiplying the scores of the parameters with their respective weights and the results are shown in Table 3.

3.3 Determination of Impact Score

This was also calculated using different parameters including population, population density, poverty rate, and urban/rural function, and the results are presented in Table 4.

3.4 Drainage Risk Score Calculation and Mapping

The drainage risk score was calculated by multiplying the exposure and impact scores and the results are presented in Table 5 and plotted in the map shown in Figure 1.

Table 3. Exposure Score Calculation

Sub District	Urban Village	Percentage of Inundation Area		IRS Score		OPD Perceptions		Score	Exposure Score
		Data (%)	Normalization Score	Data	Normalization Score	Data	Normalization Score		
		70%		24%		6%			
North Cimahi	Cipageran	0.71%	2	47	4	2.4	1	2.4	3
	Citeureup	1.08%	3	47	4	2	1	3.1	4
	Cibabat	0.66%	2	46	4	2.4	1	2.4	3
	Pasirkaliki	0.09%	1	47	4	2	1	1.7	2
Central Cimahi	Cimahi	0.22%	1	46	4	2.4	1	1.7	2
	Karangmekar	0.02%	1	46	4	2	1	1.7	2
	Padasuka	1.83%	4	46	4	2.4	1	3.8	4
	Setiamanah	0.97%	3	46	4	2.4	1	3.1	4
	Baros	0.25%	1	47	4	2	1	1.7	2
	Central Cigugur	1.31%	3	40	1	2.4	1	2.4	2
South Cimahi	Utama	0.45%	1	40	1	2.2	1	1	1
	Leuwigajah	0.52%	2	47	4	2.2	1	2.4	3
	Cibeber	0.05%	1	47	4	2.4	1	1.7	2
	Cibeureum	0.54%	2	40	1	2	1	1.7	1
	Melong	1.00%	3	46	4	3.4	4	3.3	4
Maximum Value								3.8	-
Minimum Value								1	-
Interval								2.8	-

Table 4. Impact Score Calculation

Sub District	Urban Village	Population		Population Density		Poverty Rate		Urban/Rural Function Score	Score	Impact Score
		Data (%)	Normalized Score	Data (Person /Ha)	Normalized Score	Data (%)	Normalized Score			
		44%		32%		17%		7%		
North Cimahi	Cipageran	8.63	3	145	1	4.7	1	2	2.0	2
	Citeureup	6.87	2	212	2	5.1	1	2	1.8	2
	Cibabat	9.77	4	340	4	5.2	1	2	3.4	4
	Pasirkaliki	3.40	1	267	2	4.9	1	2	1.4	1
Central Cimahi	Cimahi	2.40	1	285	3	9.8	4	2	2.2	2
	Karangmekar	2.97	1	226	2	7.9	3	2	1.7	1
	Padasuka	7.10	3	358	4	7.9	3	2	3.3	4
	Setiamanah	4.24	1	308	3	8.3	3	2	2.1	2
	Baros	3.83	1	170	1	5.8	1	2	1.1	1
	Central Cigugur	8.64	3	367	4	10.6	4	2	3.4	4
South Cimahi	Utama	6.28	2	165	1	8.1	3	2	1.9	2
	Leuwigajah	8.12	3	206	1	6.9	2	2	2.1	2
	Cibeber	4.97	2	149	1	6.3	2	2	1.7	1
	Cibeureum	11.0	4	402	4	10.9	4	2	3.9	4
	Melong	7.00	4	374	4	4.7	1	2	3.4	4
Maximum Value									3.9	-
Minimum Value									1.1	-
Interval									2.8	-

Table 5. Drainage Risk Score

Sub District	Urban Village	Exposure Score	Impact Score	Score Total	Drainage Risk Score	Note
North Cimahi	Cipageran	3	2	6	2	Low risk
	Citeureup	4	2	8	2	Low risk
	Cibabat	3	4	12	3	High risk
	Pasirkaliki	2	1	2	1	Very low risk
Central Cimahi	Cimahi	2	2	4	1	Very low risk
	Karangmekar	2	1	2	1	Very low risk
	Padasuka	4	4	16	4	Very high risk
	Setiamanah	4	2	8	2	Low risk
	Baros	2	1	2	1	Very low risk
	Central Cigugur	2	4	8	2	Low risk
South Cimahi	Utama	1	2	2	1	Very low risk
	Leuwigajah	3	2	6	2	Low risk
	Cibeber	2	1	2	1	Very low risk
	Cibeureum	1	4	4	1	Very low risk
	Melong	4	4	16	4	Very high risk
Maximum Value				16	-	-
Minimum Value				2	-	-
Interval				14	-	-

Source: Calculation Result, 2019

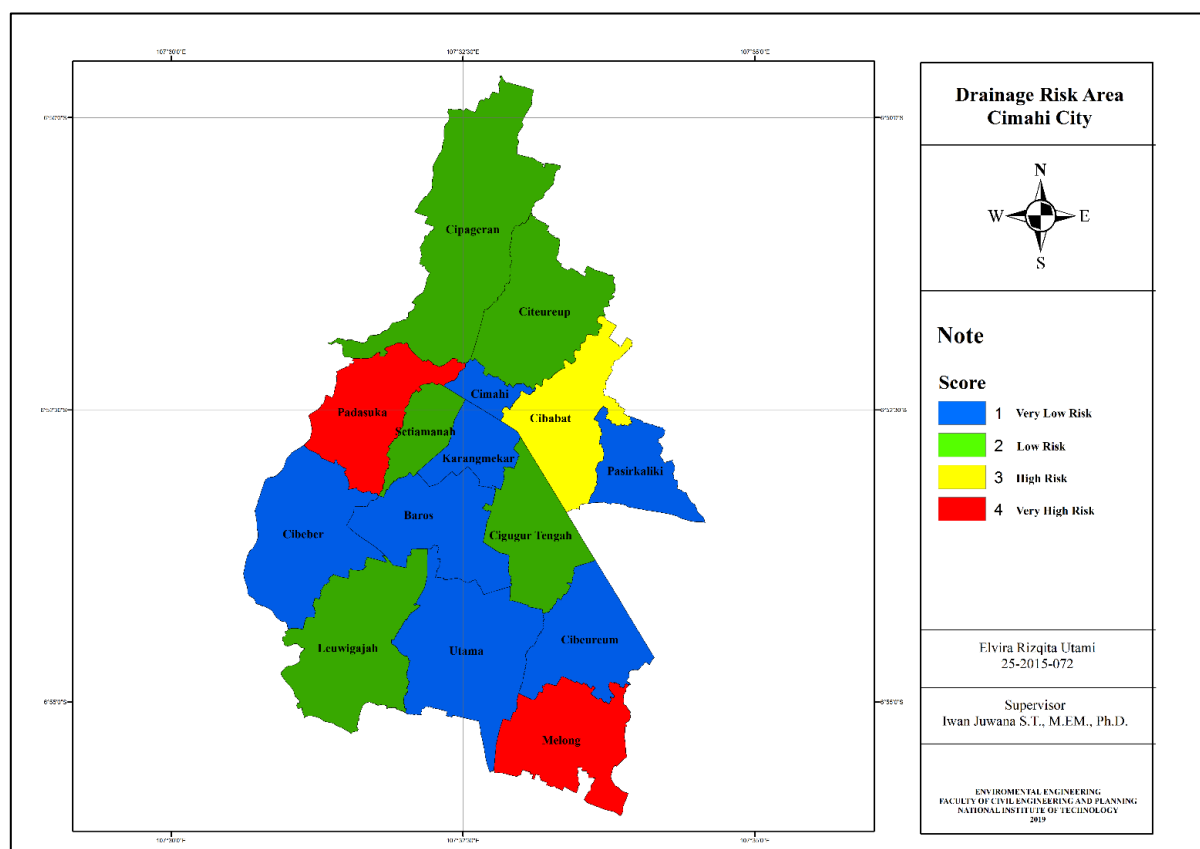


Figure 1. Mapping Drainage Risk Area in Cimahi City

Figure 1 shows Melong and Padasuka urban villages are considered to have a very high risk of drainage issues as evident in the very low values recorded for their exposure and impact factors based on a high number of inundations areas, low number of IRS, low value from related local government officials' opinions as well as high population density and poverty rate.

The results also showed Pasirkaliki, Karangmekar, Cibeber, Baros, Cimahi, Utama, and Cibeureum have lesser inundation areas, a higher number of IRS, lower poverty rates, and significantly lower population density and these were observed to produced lower values for the overall drainage score. This, therefore, means these areas have very low drainage risk.

The drainage risk calculation also showed the exposure weight is significantly higher than the impact weight and this is observed to be due to the direct relation of the impact factors with the drainage issues while exposure factors are not significantly or directly related to these issues. This study, therefore, shows some of the urban villages have a high risk of impact factors but a low risk of exposure factors, thereby, leading to their overall lower drainage risk. This is observed in Cibeureum which was recorded to have a very low risk for exposure factors as shown by value 1 but very high risk for impact factors as indicated by 4, thereby, leading to an overall risk of 1 or very low based on weights.

4 CONCLUSION

The research showed the urban villages included in very low risk with a score of 1 include Pasirkaliki, Cimahi, Karangmekar, Baros, Utama, Cibeber, and Cibeber. Those having low risk with a score of 2 were Cipageran, Citeureup, Setiamanah, Central Cigugur, and Leuwigajah. The villages classified as having high risk or score of 3 were Cibabat while those with very high risk or score of 4 were Padasuka and Melong. The results also showed the weights for impact and exposure factors have significant effects on the

overall drainage risk such that the areas with higher weights of exposure factors are classified as having low drainage risk even though they have high-risk values for impact factors. It is recommended that decision-makers in Cimahi City use the risk map to develop relevant strategies to address drainage problems in the future.

DISCLAIMER

The authors declare no conflict of interest.

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