IDRIM VIRTUAL WORKSHOP
for Interactive Discussions between Senior and Early-Career Scientists
September 23rd – 24th, 2020
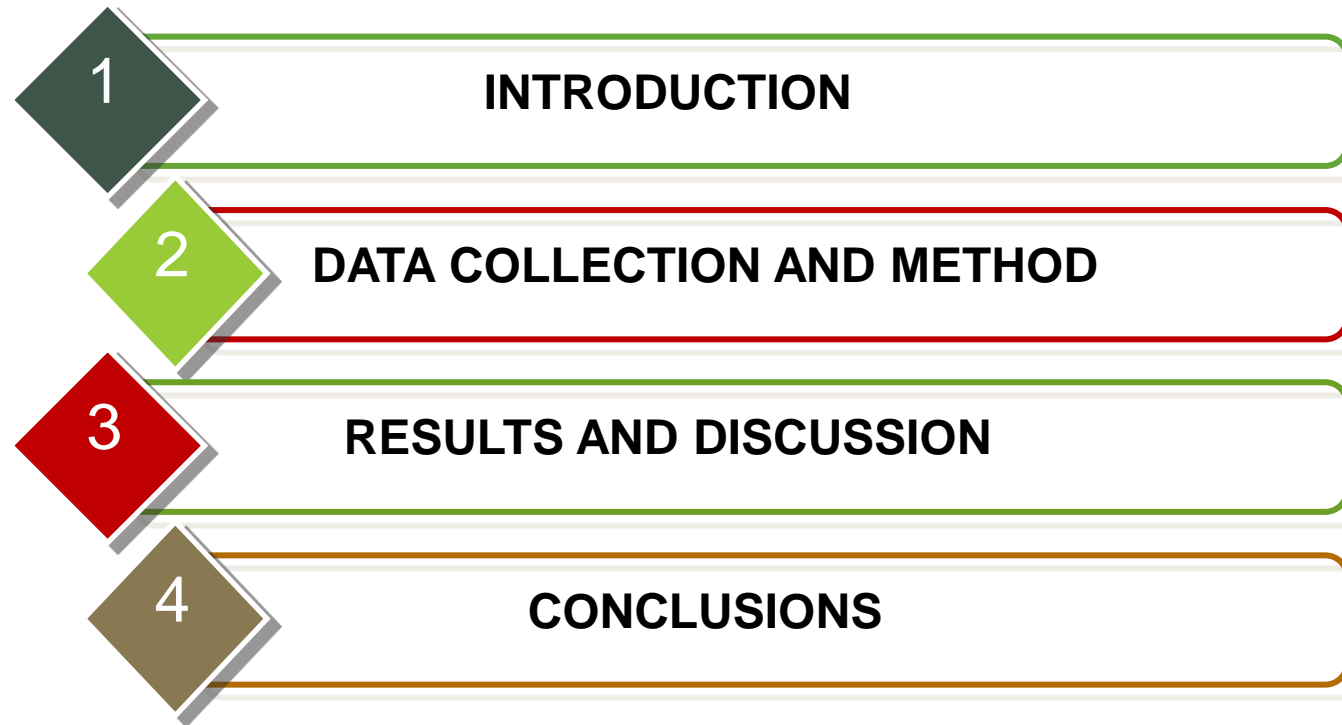
Presented by:

Faizul Chasanah
Hiroyuki Sakakibara

ASSESSMENT OF SOCIAL VULNERABILITY IN EVACUATION PROCESS FROM MOUNT MERAPI:
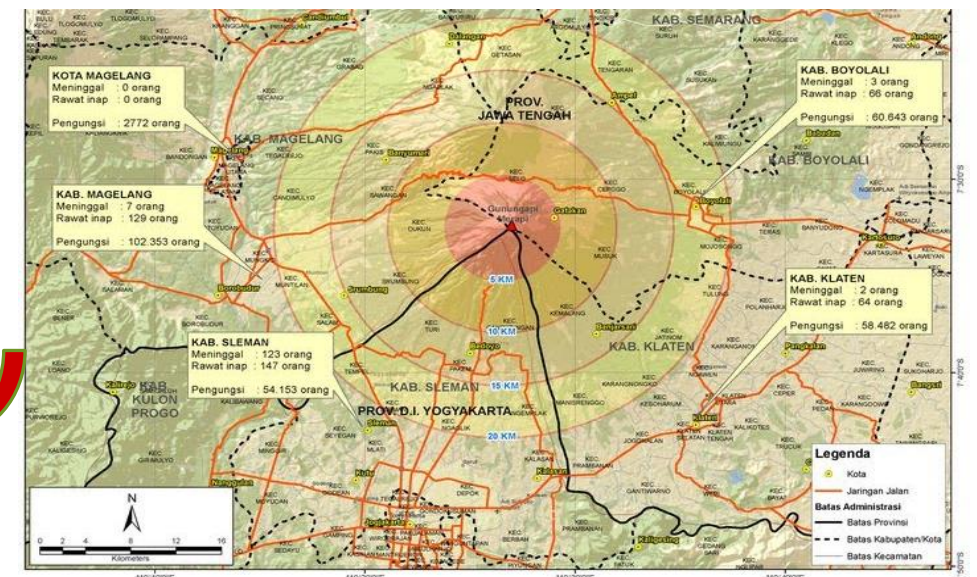*Focusing On People's Behavior And Mutual Assistance*

CONTENT

1 INTRODUCTION

2 DATA COLLECTION AND METHOD

3 RESULTS AND DISCUSSION

4 CONCLUSIONS

INTRODUCTION

(1) Mount Merapi Location

Regencies	Survey Site
Boyolali **(11 villages)**	Tlogolele, Klakah, Jrakah, Lencoh, Samiran, Surotoleng, Wonodoyo, Jombong, Cluntang, Mriyan, and Sanggup
Klaten **(5 villages)**	Balerante, Tegalmulyo, Sidorejo, Panggang, and Bawukan
Magelang **(19 villages)**	Kaliurang, Nglumut, Ngablak, Ngargosoko, Tegalrandu, Mranggen, Srumbung, Kemiren, Kapuhan, Wonolelo, Ketep, Ngargomulyo, Sewukan, Sumber, Kalibening, Keningar, Sengi, Krinjing, and Paten
Sleman **(24 hamlets)**	Ngandong, Nganggring, Tunggularum, Gondoarum, Sempu, Manggungsari, Turgo, Ngepring, Kemiri, Boyong, Ngipiksari, Kaliurang Timur, Kaliurang Barat, Pelemsari, Pangukrejo, Jambu, Kopeng, Batur, Pagerjurang, Kepuh, Manggong, Kalor, Kalkid, and Srunen

Source: National Disaster Management Authority (2010)

INTRODUCTION

(2) Merapi Volcano Activity

Merapi Volcano - Time Between Eruptions (past 200 years)

Source: Research and Development Center for Geological Disaster Technology (BPPTKG) (2020)

2020, January 4th and February 13rd

2020, March 3rd 27th 28th 29th

2020, April 2nd 4th and June 21st

Source: Research and Development Center for Geological Disaster Technology (BPPTKG) (2020)

INTRODUCTION

(3) Research Background

Merapi Eruption Impact (2010)

- A disaster management crisis (impact of the eruption was ranked third in the world) → (Guha-Sapir et al. 2016)
- Congestion and evacuation delay (> 400,000 people evacuated and > 50,000 people refuse to evacuate)→ (Mei et al. 2013)

The Local Government Issue

- The government contingency plans have been updated by 2020 but the people's behavior has not been fully considered in vulnerability assessment
- "Sister Village" scenario has been coordinated but the government will prioritize to evacuate vulnerable people from meeting area to shelter → All resident will self-evacuate from their homes to the meeting area (potential to congestion and traffic accident)

Previous Study

- The Merapi risk assessment result shows that there is still a large risk in the Sleman Regency → Nugraha et al. (2019)
- The simultaneous strategy has better performance to reduce the risk and staged strategy has better ability to reduce traffic jam → Jumadi et al. (2019)
- The total evacuation time can be reduced if 20% of the pedestrians slow down → (Zou et al. 2020)

Documentation of Evacuation Process during Merapi Disaster in 2010

INTRODUCTION

(4) Objective

Identification of effective evacuation time

> 1. To observe the walking speed of the evacuation simulation in each village affected

New strategies for the vulnerable people safety

> 2. To analyze the community behavior and mutual assistance

Comprehensive social vulnerability assessment

> 3. To assess the social vulnerability index of social and age structure factor, and risk perception factor.

"Mutual Assistance" is very important
(Young people help vulnerable people to evacuate)

Vulnerable People

DATA COLLECTION AND METHOD

(1) Conducting Survey

The Purpose Sampling Method

Secondary data
- Regional Contingency Plan Document
- Village Contingency Plan Document

The questionnaire instrument used was tested for validity and reliability using SPSS software (The test is done at 5% level of significance)

Primary Data
- Walking speed measurement of 518 volunteers (77 by Boyolali, 37 by Klaten, 184 by Magelang, 220 by Sleman)
- Interviews with 50 stakeholder (16 by Boyolali, 8 by Klaten, 16 by Magelang, 10 by Sleman)
- Forum group discussion with 658 local communities (136 by Boyolali, 60 by Klaten, 184 by Magelang, 278 by Sleman)

DATA COLLECTION AND METHOD

(1) Conducting Survey

1 **Walking Speed Measurement**
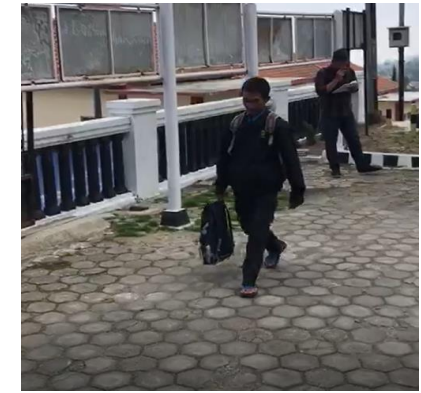

Young without baggage

Young with baggage

➢ The volunteers were asked to walk through a route for about 250 m to 500 m distance

➢ The observer used a walking measure tool, timer, and handy cam to record the data

Young and disability (wheelchair)

Young and disability (autism child)

Young and elderly
Young and child
Young and pregnant mother

<u>**8 types of the volunteers**</u>:
1. Young people (were represented by ages 12 to 59 years old)
2. Children (were represented by ages 5 to 11 years old)
3. Pregnant mother (were represented by more than 3 months of pregnancy)
4. Breastfeeding mother (are mothers carrying babies and toddlers)
5. Elderly (more than 60 years old)
6. Disability (have physical abnormalities)
7. Driver (who own private cars and trucks) ⟶ not measured speed but join in FGD
8. Breeder (having cattle and or goats) ⟶ not measured speed but join in FGD

Disability (limp legs)

DATA COLLECTION AND METHOD

(1) Conducting Survey

2 **Interview Stakeholder** → Interviews were conducted with the village leader and several stakeholders at Regional Disaster Management Agency

Interview with Head of Boyolali Disaster Management Agency

Interview with Secretary of Klaten Disaster Management Agency

Interview with Village leader in Wonodoyo, Boyolali

DATA COLLECTION AND METHOD

(1) Conducting Survey

3 **Forum Group Discussion with local communities**

➢ There are about 16 volunteers in each village or hamlet
➢ The volunteers were asked to fill personal identity and complete questionnaire sheet
➢ Topic of discussion is Merapi disaster experience in 2010 and evacuation planning in future (risk perception)

FGD in Samiran Village, Boyolali

FGD in Pangukerjo Village, Sleman

FGD in Panggang Village, Klaten

FGD in Nglumut Village, Magelang

DATA COLLECTION AND METHOD

Walking speed data, people's behavior, and mutual assistance impact are analyzed with descriptive statistics (mean, standard deviation, etc.) and SPSS Software (ANOVA Test and Simples T-test)

The social vulnerability index was assessed with a multicriteria method
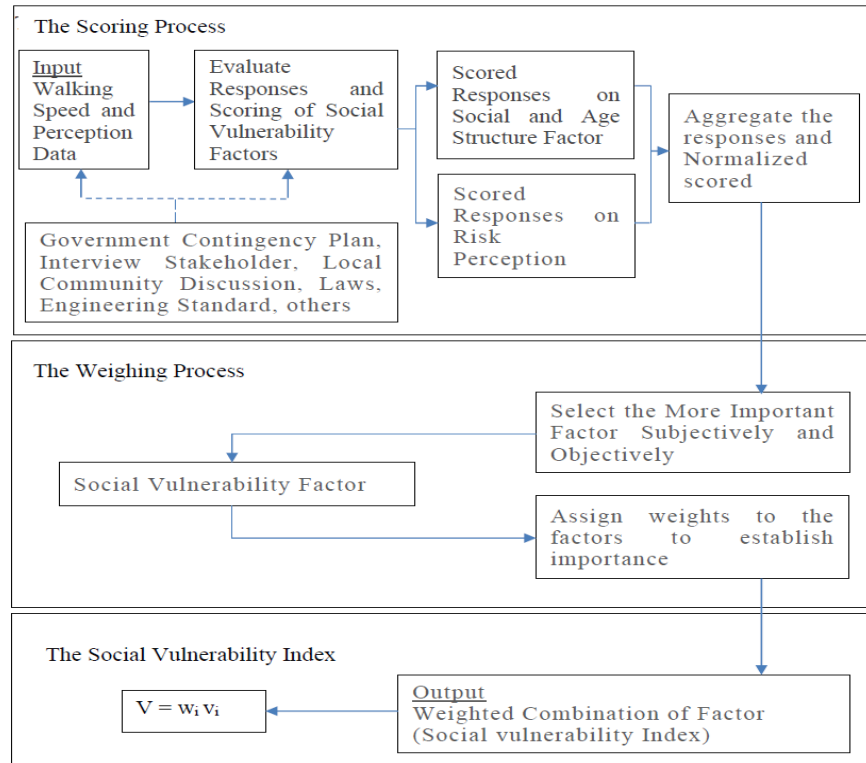
DATA COLLECTION AND METHOD

(3) Social Vulnerability Index

Velasquez (2003) ⟷

Focus on Social Vulnerability Index

$$R = \sum_{i=1,j=i,k=1}^{n,n,n} w_i H_i * (\alpha_{ijk}) w_j V_{ij}$$

$$V = \sum w_i v_i$$

Where V = vulnerability index, w_i = weight of factor i, and v_i = criterion score for vulnerability factor i.

The Scoring Process

Input Walking Speed and Perception Data → Evaluate Responses and Scoring of Social Vulnerability Factors → Scored Responses on Social and Age Structure Factor → Aggregate the responses and Normalized scored

Scored Responses on Risk Perception

Government Contingency Plan, Interview Stakeholder, Local Community Discussion, Laws, Engineering Standard, others

The Weighing Process

Social Vulnerability Factor

Select the More Important Factor Subjectively and Objectively

Assign weights to the factors to establish importance

The Social Vulnerability Index

$V = w_i v_i$ ← Output Weighted Combination of Factor (Social vulnerability Index)

The assessment framework

1) Determine the relative weight
   Evaluate all respondent data and scoring based on the average delay evacuation categorized as vulnerable. A score of delayed evacuation is 1 and the score of direct evacuation is 0. Where R = raw score.
2) Normalized the score
   Normalize the factors to 0-1 (0 not vulnerable, 1 = vulnerable).
   Where $Xi = (R_i-R_{min})/(R_{max}-R_{min})$.
3) Calculate the criterion weights
   Subjectively, the factor weights and normalized weight of important reveal are decided. Assigning criteria uses a simple pairing procedure utilizing at nine step scale. This value indicates the relative scale of importance including 1/9, 1/7, 1/5, 1/3, 1, 3, 5, 7, and 9. The meaning of 1/9 is less important, 1 is standard, and 9 is more important.
4) Reveal the weighted linier combination of factor
   Social vulnerability index = $w_1v_1 + w_2 v_2 + \ldots + w_n v_n$

DATA COLLECTION AND METHOD

(3) Social Vulnerability Index

Scoring criterion design of the social and age structure factor

Categories	Score	Description	Description to Consider (values)
Young People **Vulnerable People** **Mutual Assistance Group**	0	Not Vulnerable	Faster than mean walking speed standard ($\geq$ 1.4 m/s)*
	1	Vulnerable	Slower than mean walking speed standard (< 1.4 m/s)*

*Source: Yosritzal et al. (2018)

Scoring criterion design of the risk perception factor

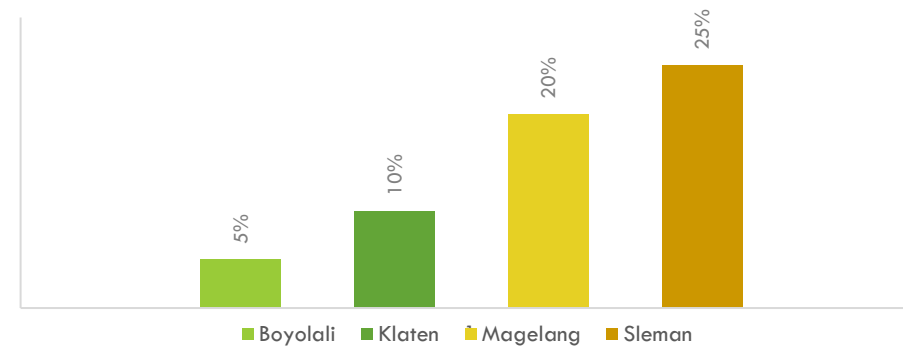| Score	Description	Description to Consider (values)
Work condition		
0	Not Vulnerable	Direct evacuation to waiting area
1	Vulnerable	Returned home to meet family
Rain condition		
0	Not Vulnerable	Direct evacuation to waiting area
1	Vulnerable	Delay until the rain stop
Night condition		
0	Not Vulnerable	Direct evacuation to waiting area
1	Vulnerable	Delay until morning
Alert condition		
0	Not Vulnerable	Direct evacuation to waiting area
1	Vulnerable	Delay until see eruption
Understanding of destination		
0	Not Vulnerable	Understand the waiting area
1	Vulnerable	Do not understand the waiting area

RESULT AND DISCUSSION

(1) Local Communities Characteristics

➢ Similar characteristics in the four affected regencies
  1. The majority of the local community's livelihoods are agriculture and livestock farming.
  2. The largest population is young people
  3. The most of residents stay in the villages during the daytime
  4. The proportion of single elderly people is exceedingly small (live with their family)
  5. The social culture with neighbors is good and help each other ("Mutual Assistance" is possible to conduct)
➢ The government will focus to evacuate vulnerable people and then young people without a private vehicle
➢ The effectiveness of pedestrian evacuation time from the house to the meeting area is crucial because of the uncertainty on the interval for changing from level 3 to 4 (eruption) status

Young People Population Data

	Boyolali	Klaten	Magelang	Sleman
	64%	64%	81%	72%
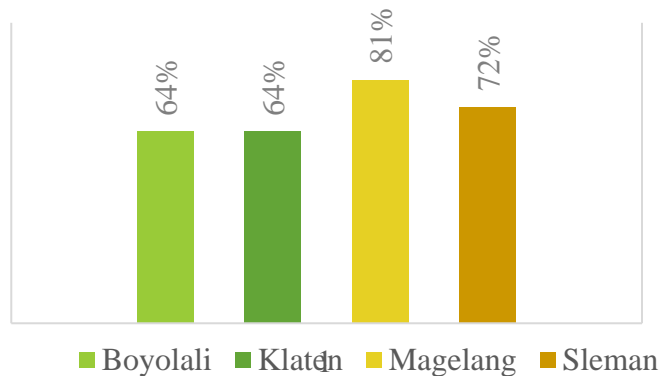
Student and workers data who are outside the residence village

	Boyolali	Klaten	Magelang	Sleman
	5%	10%	20%	25%

RESULT AND DISCUSSION

(1) Local Communities Characteristics

Conceptual of Regency Population
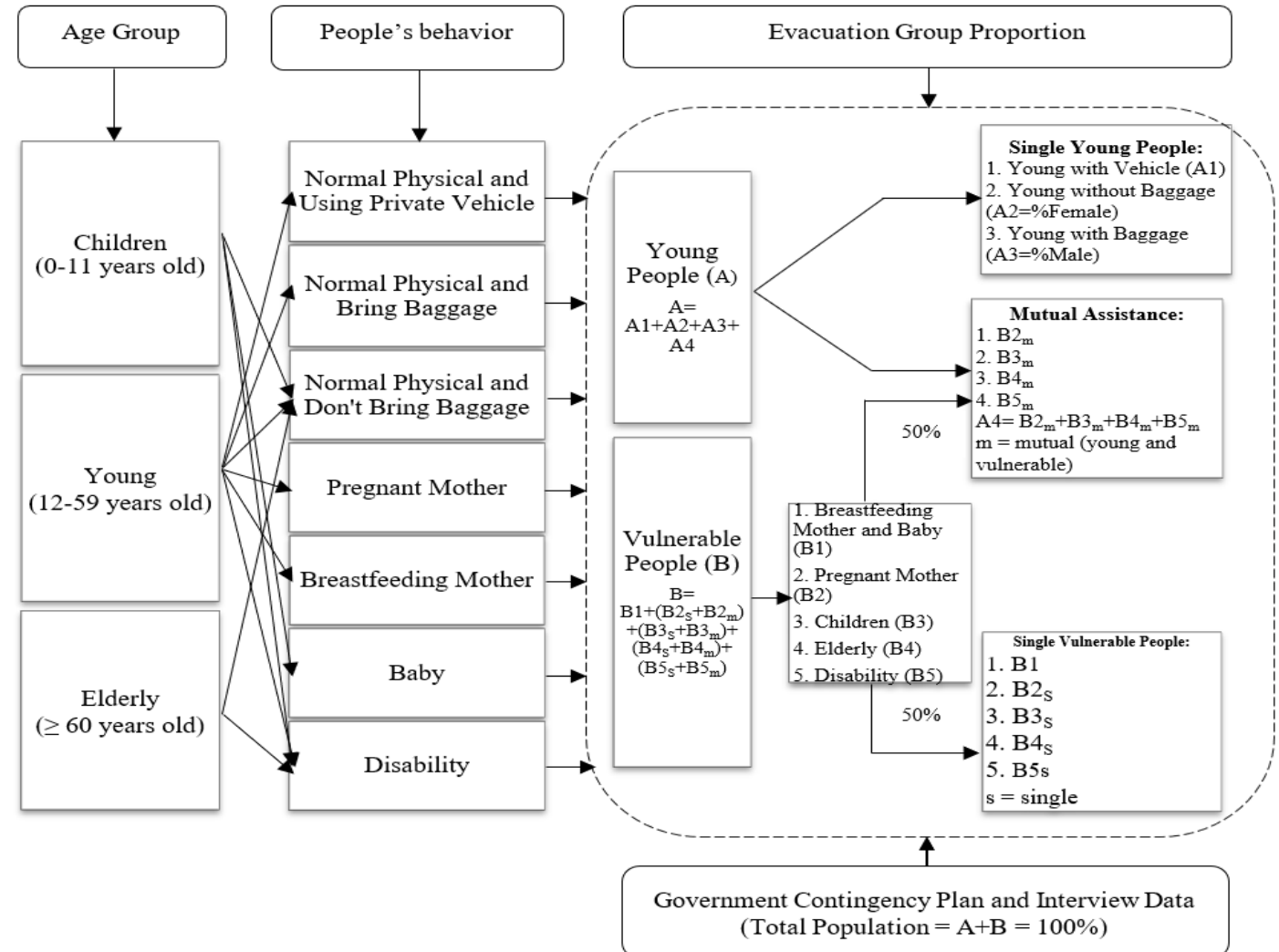
RESULT AND DISCUSSION

(2) Pedestrian Evacuation Speed

Pedestrian evacuation speed in Boyolali Regency

Categories	Number	Walking Speed (m/s) [Mean and Standard Deviation]	Range High	Range Low
Young without Baggage	18	1.48 ± 0.43	2.19	1.04
Young with Baggage	6	1.28 ± 0.23	1.51	0.97
Young and Children	5	1.45 ± 0.37	1.96	1.07
Young and Pregnant Mother	9	1.21 ± 0.29	1.67	0.83
Young and Elderly	9	1.22 ± 0.35	2.02	0.84
Young and Disability	3	0.86 ± 0.17	1.04	0.67
Breastfeeding Mother and Baby	8	1.23 ± 0.30	1.79	0.90
Pregnant Mother	8	1.25 ± 0.38	1.81	0.84
Children	4	1.22 ± 0.42	1.84	0.96
Elderly	5	0.99 ± 0.11	1.15	0.86
Disability	2	1.12 ± 0.18	1.25	1.00

Mutual assistance groups have a median speed between vulnerable and young people

Pedestrian evacuation speed in Klaten Regency

Categories	Number	Walking Speed (m/s) [Mean and Standard Deviation]	Range High	Range Low
Young without Baggage	9	1.70 ± 0.62	2.56	1.00
Young with Baggage	2	2.58 ± 0.07	2.63	2.53
Young and Children	3	1.46 ± 0.72	2.18	0.74
Young and Pregnant Mother	4	1.09 ± 0.23	1.32	0.77
Young and Elderly	4	1.45 ± 0.48	2.13	1.00
Young and Disability	2	1.44 ± 0.15	1.54	1.33
Breastfeeding Mother and Baby	4	1.60 ± 0.52	2.10	0.99
Pregnant Mother	3	1.25 ± 0.19	1.39	1.04
Children	3	1.39 ± 0.07	1.47	1.34
Elderly	2	1.38 ± 0.21	1.52	1.23
Disability	1	0.46 ± 0.00	0.46	0.46

- Klaten Regency has the highest mean speed due to the downhill road conditions and good pavement
- Boyolali Regency has a relatively flat and descending surface
- Young with baggage has a significantly higher speed because the topographic contours tend to decrease and running action
- Disabled person in Klaten Regency has the lowest speed (0.46 m/s) due to leg defect and old age

RESULT AND DISCUSSION

(2) Pedestrian Evacuation Speed

Pedestrian evacuation speed in Magelang Regency

Categories	Number	Walking Speed (m/s) [Mean and Standard Deviation]	Range High	Range Low
Young without Baggage	75	1.25 ± 0.26	1.85	0.79
Young with Baggage	2	0.80 ± 0.42	1.10	0.50
Young and Children	12	1.78 ± 0.38	2.33	1.25
Young and Pregnant Mother	9	1.02 ± 0.43	1.52	0.44
Young and Elderly	9	1.10 ± 0.46	1.39	0.40
Young and Disability	7	1.05 ± 0.51	1.79	0.55
Breastfeeding Mother and Baby	18	0.90 ± 0.39	1.45	0.55
Pregnant Mother	15	0.87 ± 0.39	1.45	0.40
Children	11	1.36 ± 0.33	1.83	1.05
Elderly	15	0.95 ± 0.44	1.94	0.39
Disability	11	0.88 ± 0.45	1.47	0.39

Pedestrian evacuation speed in Sleman Regency

Categories	Number	Walking Speed (m/s) [Mean and Standard Deviation]	Range High	Range Low
Young without Baggage	56	1.23 ± 0.18	1.64	0.99
Young with Baggage	14	0.95 ± 0.16	1.23	0.67
Young and Children	6	1.08 ± 0.16	1.25	0.81
Young and Pregnant Mother	11	1.02 ± 0.15	1.28	0.73
Young and Elderly	14	1.01 ± 0.11	1.15	0.80
Young and Disability	5	0.84 ± 0.24	1.26	0.69
Breastfeeding Mother and Baby	30	1.04 ± 0.28	1.56	0.37
Pregnant Mother	22	0.98 ± 0.33	1.43	0.32
Children	14	1.07 ± 0.26	1.57	0.63
Elderly	41	0.87 ± 0.26	1.38	0.55
Disability	7	1.11 ± 0.30	1.35	0.64

Magelang and Sleman Regencies have a combination of surfaces between flat, uphill, and downhill which cause slower speeds
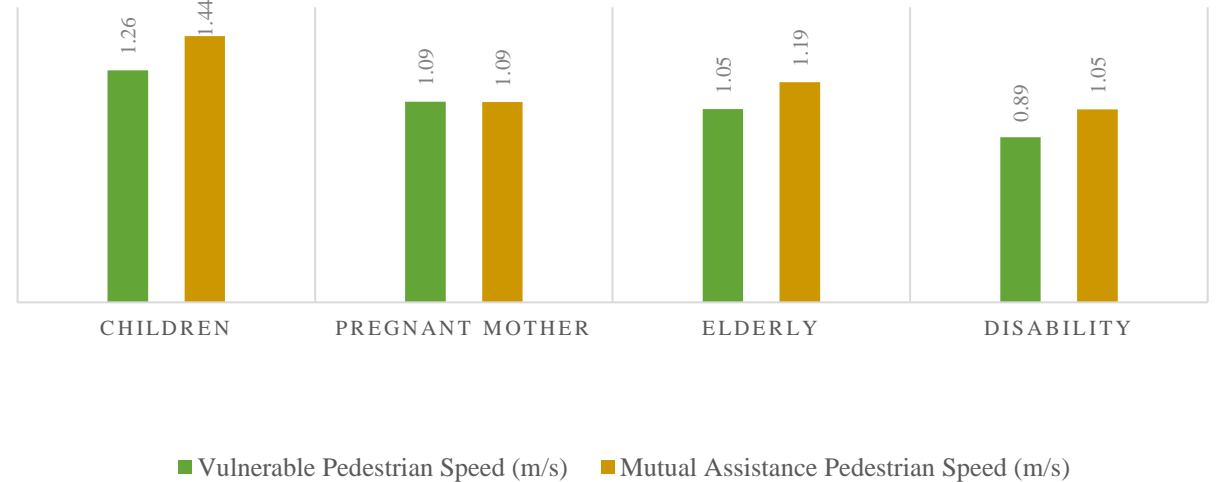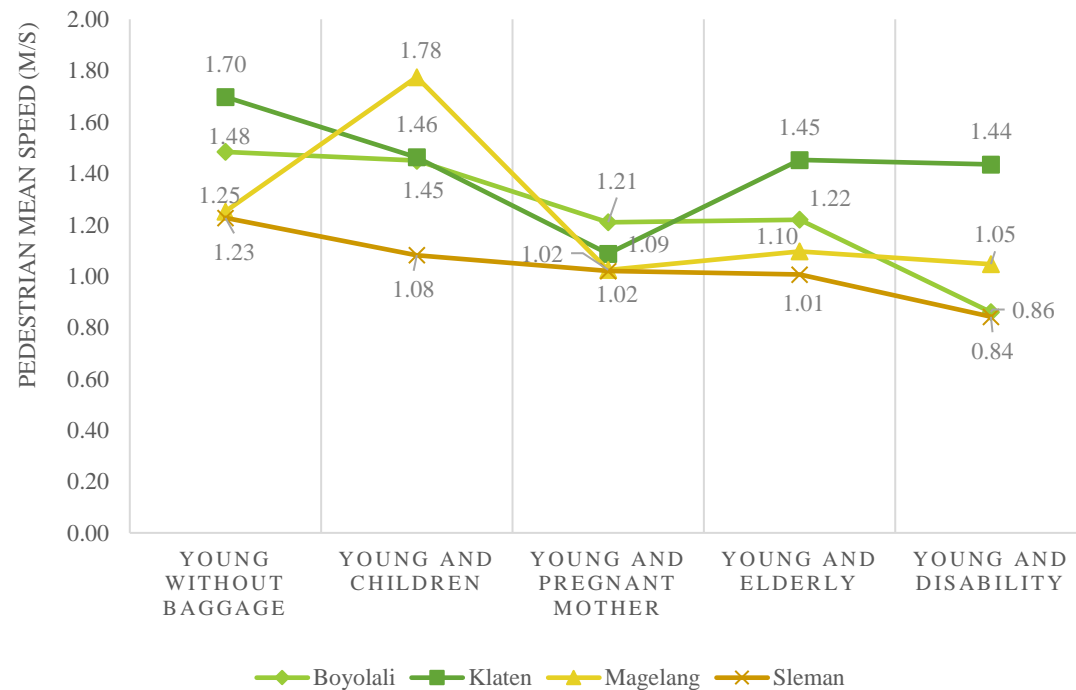
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RESULT AND DISCUSSION

(2) Pedestrian Evacuation Speed

- ➤ The mean walking speed in four regencies are not significantly different except in category of young with baggage (ANOVA result at 1% - 5 % level of significance)
- ➤ Topographic conditions for each region are different, so it affects the walking speed faster or slower
- ➤ There are many types of disability in this case including autism child, deaf, and limp legs with or without a wheelchair. So it affects the walking speed difference

Recapitulation of ANOVA result in each category (comparison between regencies)

Categories		Sum of Squares	Df	Mean Square	F	Sig.
Young People	Between Groups	.033	1	.033	1.715	.202
	Within Groups	.484	25	.019		
	Total	.518	26			
Young with baggage	Between Groups	.554	3	.185	18.076	.000
	Within Groups	.204	20	.010		
	Total	.759	23			
Young and Children	Between Groups	.318	3	.106	4.296	.016
	Within Groups	.542	22	.025		
	Total	.860	25			
Young and Pregnant Mother	Between Groups	.056	3	.019	.851	.477
	Within Groups	.640	29	.022		
	Total	.697	32			
Young and Elderly	Between Groups	.140	3	.047	1.246	.310
	Within Groups	1.161	31	.037		
	Total	1.301	34			
Young and Disability	Between Groups	.121	3	.040	1.184	.354
	Within Groups	.444	13	.034		
	Total	.565	16			
Breastfeeding Mother	Between Groups	.254	3	.085	3.338	.026
	Within Groups	1.418	56	.025		
	Total	1.672	59			
Pregnant Mother	Between Groups	.955	3	.318	2.526	.070
	Within Groups	5.544	44	.126		
	Total	6.499	47			
Children	Between Groups	.614	3	.205	2.263	.103
	Within Groups	2.533	28	.090		
	Total	3.148	31			
Elderly	Between Groups	.133	3	.044	1.591	.201
	Within Groups	1.645	59	.028		
	Total	1.778	62			
Disability	Between Groups	.485	3	.162	1.050	.396
	Within Groups	2.618	17	.154		
	Total	3.103	20			

RESULT AND DISCUSSION

(3) Mutual Assistance Impact

Vulnerable Pedestrian Speed (m/s) — Mutual Assistance Pedestrian Speed (m/s)

Chart values — Children: 1.26, 1.44; Pregnant Mother: 1.09, 1.09; Elderly: 1.05, 1.19; Disability: 0.89, 1.05

Line chart — Pedestrian Mean Speed (m/s) by group (Boyolali, Klaten, Magelang, Sleman)

- Young Without Baggage: 1.70, 1.48, 1.25, 1.23
- Young and Children: 1.78, 1.46, 1.45, 1.08
- Young and Pregnant Mother: 1.21, 1.09, 1.02, 1.02
- Young and Elderly: 1.45, 1.22, 1.10, 1.01
- Young and Disability: 1.44, 1.05, 0.86, 0.84

➢ The mean walking speed between young and vulnerable people have the significant difference (Independent samples T-test result at 5 % level of significance)

➢ Mutual assistance groups have a median speed between vulnerable and young people

➢ Children, elderly, and disabled people have a significant impact on this mutual assistance action

➢ The paired samples T-test result shows that p value (0.009) < 0.05. It describes that pedestrian evacuation speed of mutual assistance and vulnerable have significant difference at 5 % level of significance.

RESULT AND DISCUSSION

(4) Social Vulnerability Index

Common score of the social and age structure (all affected regencies)

Categories	Number	Pedestrian Speed (m/s)		Common Score (Normalized)
		Mean	Standard Deviation	
Young without Baggage	158	1.42	0.37	0.484
Young with Baggage	24	1.40	0.22	0.496
Young and Children	26	1.44	0.41	0.460
Young and Pregnant Mother	33	1.09	0.27	0.875
Young and Elderly	36	1.19	0.35	0.722
Young and Disability	17	1.05	0.27	0.908
Breastfeeding Mother and Baby	60	1.19	0.37	0.709
Pregnant Mother	48	1.09	0.32	0.834
Children	32	1.26	0.27	0.699
Elderly	63	1.05	0.25	0.919
Disability	21	0.89	0.23	0.985

Common score of the risk perception (all affected regencies)

Categories	Criterion Score				Common Score
	Boyolali	Klaten	Magelang	Sleman	
Work Condition	0.900	0.733	0.815	0.727	0.794
Rain Condition	0.080	0.117	0.103	0.061	0.090
Night Condition	0.040	0.017	0.011	0.029	0.024
Alert Condition	0.040	0.017	0.011	0.025	0.023
Understanding of Destination	0.600	0.317	0.130	0.108	0.289

Normalized the score, $Xi = (R_i - R_{min})/(R_{max} - R_{min})$
Common Score = Normal distribution = represent similar regional characteristic

RESULT AND DISCUSSION

(4) Social Vulnerability Index

Weight of vulnerability in subjective and objective view

No	Categories	Weight of Vulnerability (Subjective)	Regency Weight (Objective)			
			Boyolali	**Klaten**	**Magelang**	**Sleman**
Social and Age Structure Factor						
1	Young with Vehicle	0.000	0.488	0.432	0.130	0.439
2	Young without Baggage	0.010	0.003	0.032	0.306	0.083
3	Young with Baggage	0.029	0.003	0.032	0.301	0.082
4	Young and Children	0.087	0.200	0.200	0.025	0.144
5	Young and Pregnant Mother	0.029	0.010	0.010	0.007	0.002
6	Young and Elderly	0.087	0.070	0.070	0.104	0.083
7	Young and Disability	0.087	0.010	0.010	0.010	0.008
8	Breastfeeding Mother and Baby	0.087	0.070	0.070	0.043	0.040
9	Pregnant Mother	0.146	0.005	0.005	0.004	0.002
10	Children	0.087	0.100	0.100	0.013	0.072
11	Elderly	0.146	0.035	0.035	0.052	0.042
12	Disability	0.204	0.005	0.005	0.005	0.004
Risk Perception Factor						
1	Work Condition	0.310	0.012	0.026	0.048	0.048
2	Rain Condition	0.034	0.247	0.244	0.238	0.238
3	Night Condition	0.034	0.247	0.244	0.238	0.238
4	Alert Condition	0.517	0.247	0.244	0.238	0.238
5	Understanding of Destination	0.103	0.247	0.244	0.238	0.238

RESULT AND DISCUSSION

(4) Social Vulnerability Index

Social vulnerability index comparison

Regencies	Index of Social and Age Structure Factor		Index of Risk Perception Factor	
	Subjective	Objective	Subjective	Objective
Boyolali	0.806	0.324	0.292	0.115
Klaten	0.806	0.352	0.292	0.124
Magelang	0.806	0.494	0.292	0.139
Sleman	0.806	0.338	0.292	0.147

➤ The index on social and age structure was higher than those on risk perception
➤ The subjective social vulnerability index was the same in four affected regency because of similar regional characteristic and can be represented by a common score
➤ Magelang Regency has the biggest objective index on social and age structure factor due to the largest population than other regencies
➤ Sleman Regency has the highest objective index on risk perception factor due to the largest worker outside in the village

CONCLUSION

❑ The mean walking speed between young and vulnerable people have the significant difference.

❑ The mutual assistance can be effective to reduce risk during evacuation. Probably, the reduced evacuation time is not so big but vulnerable people may be left if young people do not care about them.

❑ The subjective social vulnerability index was high in each regency. That means that people in local communities focusing on the evacuation problem of vulnerable people

❑ The objective index was low because the proportion of elderly people is still low in the communities.

❑ However, in the future, the proportion of elderly people will increase also in Indonesia, then vulnerability can increase objectively too.

Thank You Very Much