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MASS EVACUATION AT BANDA ACEH TRIGGERED BY Mw 8.6 EARTHQUAKE OFF THE WEST COAST OF NORTHERN SUMATRA

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Abstract

At 15:38 on Wednesday, April 11, 2012, a magnitude Mw 8.6 earthquake occurred in the Indian Ocean off the west coast of northern Sumatra, Indonesia. The epicenter was 400 km from Banda Aceh, the capital city of Aceh Province in northwest Sumatra. There was almost no damage to structures due to shaking, and no destructive tsunami occurred. However, in Banda Aceh, the Indian Ocean tsunami in December 2004 killed about 70,000 people, one quarter of the population. Residents who felt the earthquake were afraid of a tsunami and about 100,000 people evacuated in a disorderly manner from the coastal area to safe locations. As a result, heavy traffic jams occurred on various parts of main roads, and confusion continued throughout the day.

This event was equivalent to a real-scale evacuation experiment without notice. The authors interviewed 1,065 people, 0.73% of the coastal population of Banda Aceh, to determine their evacuation situation and to record the evacuation routes of 786 people. Based on these interviews, we analyzed the evacuation performance of residents, the features of evacuation route selection and the characteristics of places where traffic congestion occurred. This will provide useful information for improving future tsunami evacuation measures for Banda Aceh and for coastal cities with similar tsunami hazard risks.

Keywords: Banda Aceh, tsunami evacuation, traffic jam, interview survey, evacuation route analysis

1. Introduction

1.1 Banda Aceh and earthquakes on April 11, 2012

Banda Aceh is the capital of Aceh province at the northwestern tip of Sumatra, with a current population of 265,111 (2018 data, [1]) and an area of 61.36 km^2. The Indian Ocean tsunami on December 28, 2004 killed about a quarter of the population and destroyed half of the city. Thanks to the efforts of survivors and strong support from the Indonesia government and abroad, the city has been rebuilt and the population has recovered and increased. However, the residents' fear of tsunami has not disappeared, and the news of the March 2011 Great East Japan Earthquake and tsunami reminded Banda Aceh residents of this fear.

An Mw 8.6 earthquake occurred at 15:38 on Wednesday, April 11, 2012 in the seabed off the west coast of northern Sumatra, about 400 km from Banda Aceh. BMKG (Agency for Meteorology, Climatology and Geophysics, Indonesia) issued a

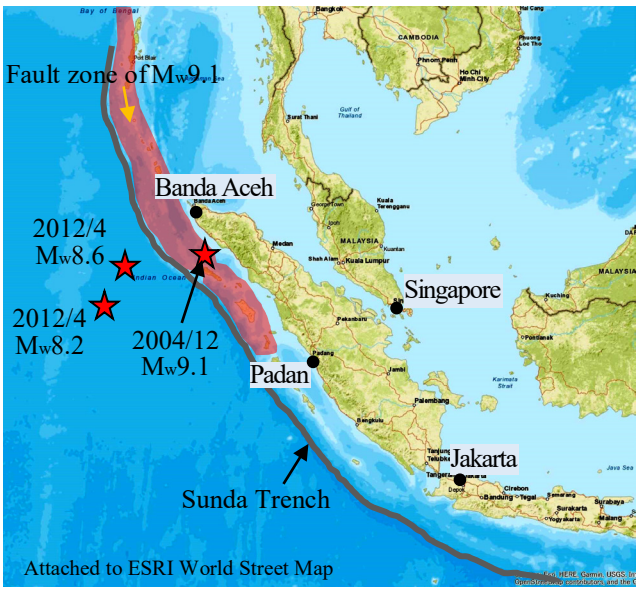

Fig. 1 – Location of Banda Aceh and Epicenters

tsunami warning about 5 minutes after the earthquake. Two hours later, at 17:43, a Mw8.2 earthquake occurred south of the first earthquake, and BMKG continued to issue the warning [2]. Fortunately, the source faults of the two earthquakes were of the strike-slip type and no tsunami that would cause significant damage occurred. The damage caused by the shaking was also small.

Photo 1 – Evacuation traffic jams on a road of Banda Aceh
(Courtesy of Serambi News Company)

However, the first quake was large enough to cause a massive evacuation panic among Banda Aceh residents as shown in Photo 1. BMKG observed this ground motion at a strong-motion seismograph about 6 km south-southwest of the center of Banda Aceh. The wave record indicated that shaking close to 20 gal continued for about 1 minute. The Japan Meteorological Agency's seismic intensity calculated from the records is 3.3, and is estimated to be approximately V based on MM seismic intensity. This seismometer is installed at the foot of a mountain, and it is presumed that the shaking of the center and the coastal area of Banda Aceh that spread on sedimentary ground was greater than that.

1.2 Tsunami warning transmission and residents' responses

The tsunami warning issued by BMKG was transmitted to the media, and seven TV stations in Indonesia broadcast them via special programs and/or telos within 6 to 12 minutes of the earthquake. Some areas of Banda Aceh did not immediately lose power after the earthquake. While the electric power company stopped supplying electricity in all city areas 19 minutes after the earthquake to prevent the damage from spreading, a limited number of residents could watch TV for about ten minutes to check for a tsunami warning. The community FM radio station in Banda Aceh, which is said to have many listeners, did not have a hotline to get warnings from BMKG. Four tsunami warning sirens that were remotely controlled by BMKG were installed in Banda Aceh, but for some reasons they did not work. Two of the sirens were repaired by technicians and started sounding 40 minutes and 1 hour after the earthquake [3].

Despite the tsunami warning not being transmitted effectively, most residents began to evacuate due to the shaking. Banda Aceh is located on flat land with low altitude, so evacuees had to go inland or to the upper floors of robust buildings. More than 100,000 evacuated inland. 73% used motorcycles and 13% used cars, causing traffic jams in various parts of the city. The turmoil continued until the next morning as the late-rung siren was mistaken for a tsunami arrival alert, and the second earthquake had also occurred. Six related deaths were reported in Aceh province. In Banda Aceh, one person, 70 years old, died from a heart attack.

2. Survey on Evacuation Behavior

This massive evacuation was a full-scale blind test that tested the tsunami evacuation potential of Banda Aceh and its residents. Therefore, by investigating and analyzing residents' performance, valuable information could be obtained to improve tsunami evacuation performance. The authors, with the cooperation of one research assistant and 11 students at Syiah Kuala University in Banda Aceh, conducted an interview survey on the behavior of 1,065 residents [4]. The study area was the area that was heavily damaged by the 2004 Indian Ocean tsunami. The interviewer brought a questionnaire sheet with 34 questions shown in Table 1, and filled in the answers of the interviewees. It was difficult to apply an ideal rule to select interviewees from among the residents. Therefore, a target number was set for each village (see Fig. 3 below), and the interviewer tried to sample the age and gender without bias. The interviewees who actually took evacuation action, were asked to describe their evacuation routs and their answers were recorded.

Table 1 – Questionnaire items

1	Interviewee name
2	Age and sex
3	Address
4	Main job
5	Educational background
6	Where were you when the earthquake occurred?
7	Did you think tsunami would come when the earthquake occurred?
8	Did you hear a tsunami siren and take it as a warning?
9	Did you notice the large tsunami warning issued by BMKG?
10	Did you find out that BMKG cleared the warning several hours later?
11	From what source did you get the tsunami warning?
12	Did you believe the tsunami warning issued by BMKG?
13	Did you evacuate? Where did you intend to go?
14	If you evacuated, when did you start to evacuate?
15	If you evacuated, what kind of transportation method you used?
16	Were you held up by or see traffic jams while you were evacuating?
17	If you were held up by traffic jams, how much time did you lose?
18	If you evacuated, did you reach your intended final destination?
19	If you evacuated, did you stop by some places?
20	If you stopped by some places, how long did you stay there?
21	If you evacuated, how long did you take to reach your destination?
22	What was the most important reason for you to start evacuation?
23	What did you do before starting evacuation?
24	With whom did you evacuate?
25	Did you talk to any persons who had not started to evacuate?
26	When did you return to your house?
27	If you returned home before BMKG cleared the tsunami warning, why?
28	Why did you not evacuate?
29	If a large tsunami had actually come, how long do you think would take to arrive?
30	Did you or your family experience the 2004 Indian Ocean Tsunami?
31	Had you spoken about tsunami with your family?
32	Was the knowledge about tsunami that you learned at school or community education helpful?
33	Had you participated in disaster drills in your community?
34	Do you think the disaster drill was effective for the actual evacuation?

3. Results of Interview Survey

3.1 Number, age and gender distribution of interviewees

We set the number of interviewees as 1% of residents based on the population data for 2010. However, the population of Banda Aceh had soared, so it was 0.73% based on 2012 data obtained after the survey [5]. The interviewed female/male ratio is 0.73. Since the female/male ratio determined from the demographics of Banda Aceh was 0.93, the sample was 12% less female and 12% more male. Fig.3 shows the age distributions of the interviewees and the entire population of Banda Aceh (excluding those under 18th). The distribution of interviewees in their thirties and forties tended to be higher, but there was no significant deviation. The rate of young people of Banda Aceh was higher than that of the whole of Indonesia [6]. It was assumed that the number of elderly persons decreased due to 2004 tsunami disaster and that the large number of young people came to work on restoration projects.

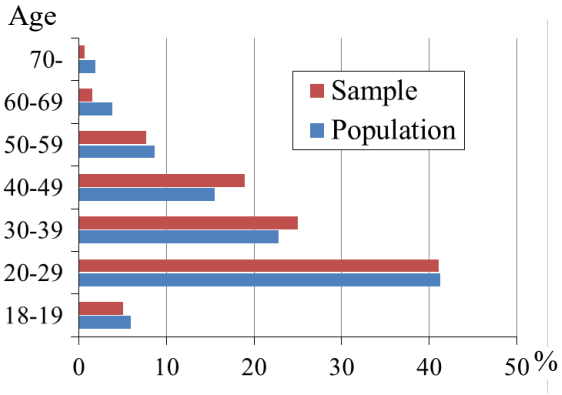

Fig. 2 – Age distribution of Sample and Population

3.2 Zone division, interviewee density and occupations

There are six administrative districts in the study area, and they are divided roughly by the line extending from the sea to inland. Therefore, in conducting the interviews, the authors divided the target area into five zones focusing on distance from the coast, as shown in Fig.3. There were 6 to 11 villages in each administrative district. Each village was categorized in the zone of the corresponding location on a village-by-village basis. Therefore, the boundaries of the zones could not be parallel straight lines. Table 2 shows the population by administrative districts and zones based on the 2012 population data and the ratios of the number of interviewees counted in their locations when the earthquake occurred to the corresponding population. The large sample rates of the yellow cells were due to erroneous excess interviews. In addition, the low sample rate of the blue cell was due to interviews aiming at reference to areas that the 2004 tsunami did not reach.

Table 3 summarizes the interviewees' occupations in each zone. There were many fishermen in Zones A and B near the coast, and many commercial persons in Zone C. Zone D was a residential area for office workers, and zone E had many students and officials of public universities.

79.5% of the residents had finished at least a high school / vocational school education.

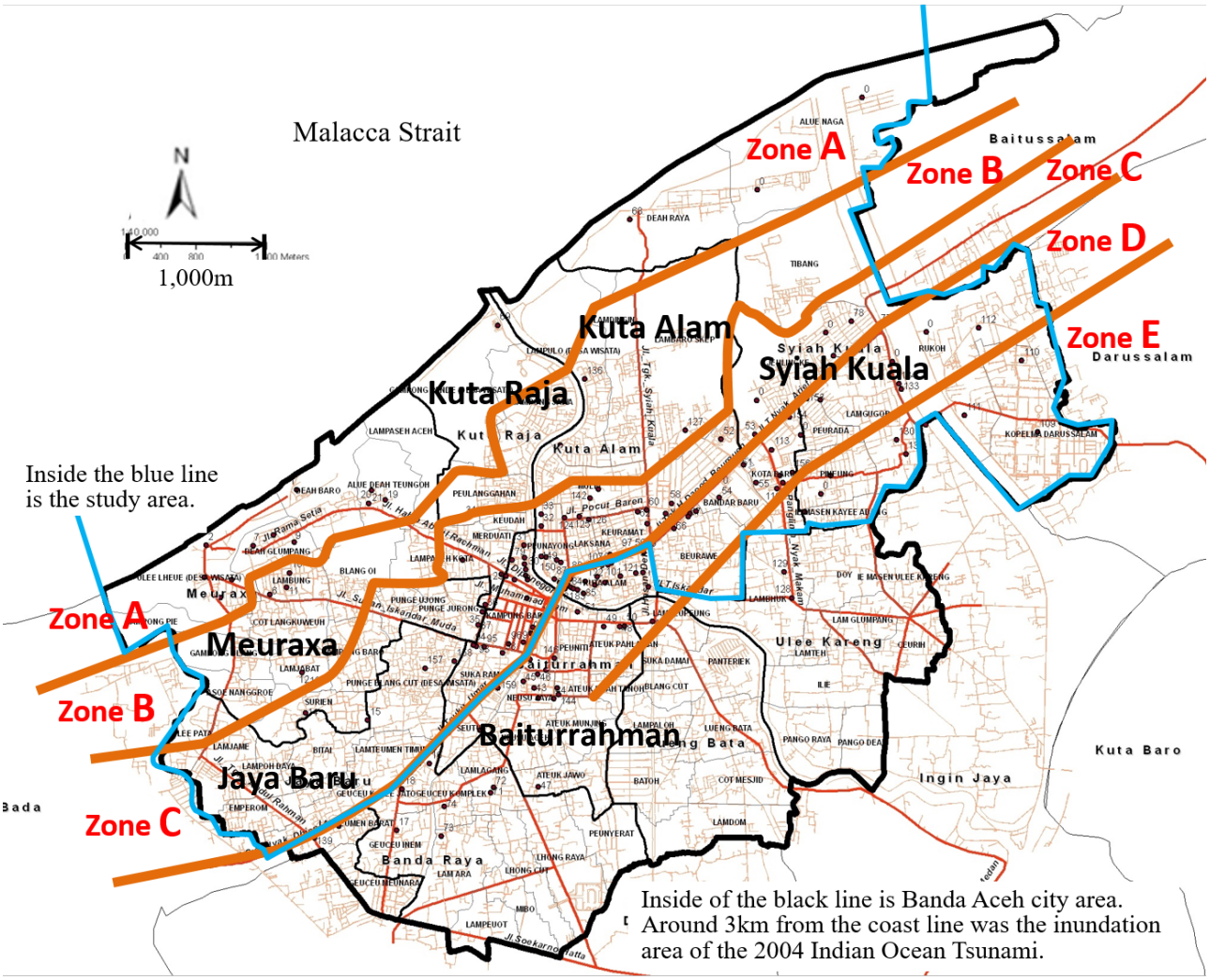

Fig. 3 – Zone divisions for the study area

Table 2 – Population by district and zone, and the population ratio of number of interviewees

	Population						Population ratio of the interviewees(%)					
District	A	B	C	D	E	Total	A	B	C	D	E	Average
Meuraxa	3,966	10,206	5,421	-	-	19,593	1.16	0.70	0.44	-	-	0.72
Kuta Raja	3,251	2,273	6,876	-	-	12,400	0.55	0.66	0.79	-	-	0.70
Kuta Alam	-	13,980	22,128	14,269	-	50,377	-	1.18	0.67	0.42	-	0.74
Syiah Kuala	2,477	1,470	6,384	12,661	13,226	36,218	1.53	1.84	0.69	0.62	0.32	0.64
Jaya Baru*	-	678	18,439	-	-	19,117	-	2.51	0.64	-	-	0.71
Baiturrahman*	-	-	8,260	-	-	8,260	-	-	0.94	-	-	0.94
Total/Average	9,694	28,607	67,508	26,930	13,226	145,965	1.05	1.03	0.69	0.51	0.32	0.72

*Populations of Jaya Baru and Baiturrahman are only inside study area.

Table 3 – Interviewees' occupations by zone

Occupation	A	B	C	D	E
Fisherman (not owing a ship)	9.6%	10.6%	5.1%	1.6%	0%
Fisherman (owing a ship)	8.7%	4.5%	1.3%	0%	0%
Farmer	0%	.5%	.5%	.8%	0%
Factory manager or owner	0%	0%	.3%	0%	0%
Shop manager or owner	6.7%	4.7%	13.1%	3.1%	13.9%
Manager or owner of service	0%	1.5%	2.8%	1.6%	0%
Contractor of a construction business	1.9%	.5%	1.3%	1.6%	0%
Salaried worker in public sector	6.7%	10.9%	13.6%	19.4%	19.4%
Salaried worker in private sector	9.6%	8.9%	13.3%	21.7%	11.1%
Stay-at-home wife	20.2%	22.3%	14.4%	11.6%	2.8%
Student	22.1%	21.8%	23.8%	27.9%	44.4%
No job	4.8%	4.0%	5.4%	6.2%	5.6%
Other	9.6	9.9%	5.3%	4.7%	2.8%
Total number	*104*	*404*	*390*	*129*	*36*

3.3 Trigger to starting evacuation

Table 4 shows the answers to the question why the interviewee started evacuation. Nearly half of responders nominated the great shake. This was the same as in the survey of areas affected by the 2011 Great East Japan Earthquake. On the other hand, one third of Banda Aceh residents answered that they evacuated because they saw neighbors evacuating. It was presumed that this was due to the limited information about a possible tsunami from public sources.

12% answered that they evacuated because they heard the tsunami siren. Fig.4 shows the evacuation start times divided into typical reasons why people evacuated. As the tsunami siren first rang 40 minutes after the earthquake, the start time triggered by the siren was clearly inconsistent. The probable reasons were as follows: Residents heard the emergency vehicles' sirens as tsunami warnings, some mosques sounded their own warnings via

Table 4 – Reasons for starting evacuation

Because I felt strong and long shaking.	44%
Because I heard tsunami siren.	12%
Because I heard that a large tsunami alert had been issued.	7%
Because I saw neighbors or many persons evacuating.	28%
Because my family insisted that we should evacuate.	7%
Because I was persuaded to evacuate by a neighbor or a community leader.	.5%
Because I was persuaded to evacuate by an official.	0%
Other	3%

large speakers, or the interviewer did not distinguish between the tsunami siren and other. In any case, it was a major problem in Banda Aceh that many residents did not know the tone of the tsunami siren and its meaning as a tsunami warning.

Although a small number, 3.9% (4 residents), in Zone A said that they were persuaded by a local community leader. Some villages of Zone A in the Meuraxa district might have formed a disaster prevention organization among residents.

3.4 Impact of TV news

Table 5 shows that 7.2% of residents obtained information from TV. As mentioned in 1.2, some areas of Banda Aceh did not immediately lose their power supply after the earthquake, so same residents were able to watch TV to check for tsunami warnings. Figs. 5 and 6 compare the evacuation behaviors of interviewees by those who obtained information from TV and those who did not. Fig. 5 shows that those who obtained information from TV evacuated in greater numbers than those who did not. Also, Fig. 6 shows that those who obtained the information from TV tended to delay first but soon after started evacuation rapidly. Watching the warning news on TV and starting evacuation within 5 minutes was contradictory, but the interviewees' senses of time might had been uncertain.

3.5 Rate of evacuation

Table 6 shows the evacuation rates by zone and gender. 90% of residents in Zone A, which is near the coast, evacuated, but the evacuation rate for men in the inland Zones B to E dropped to 54 to 73%. In particular, 19% of men in Zone B went outside and waited. They might have been affected by their experience of the 2004 tsunami, which allowed them to escape on motorcycles even after seeing the tsunami coming. However, in 2004, few people evacuated and no large-scale traffic jams occurred. It is dangerous to decide the timing of evacuation based on previous lucky experience. It is also noted in Table 6 that men were more likely not to evacuate because they tended to believe that they were already in a safe place.

3.6 Transportation method used for evacuation

Table 7 shows the means of evacuation. 73% of residents used motorcycles. However, in zone A and zone C, the rates of on-foot evacuees were relatively high. This was because there were evacuation towers,

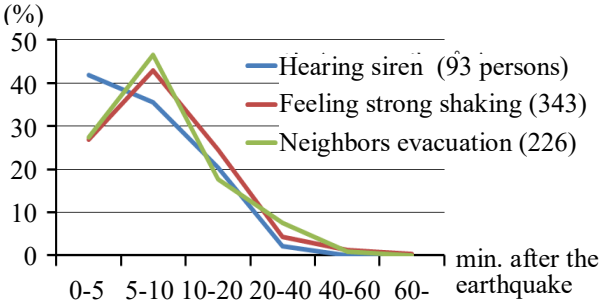

Fig. 4 – Reason vs. Evacuation start time

Table 5 – Source from which residents got tsunami alert

	A (%)	B (%)	C (%)	D (%)
TV	2.0	6.4	7.9	10.2
Radio	2.0	2.4	1.7	7.5
Loud speaker of mosque	0.0	1.0	2.1	0.7
Loud speaker of police car	1.0	0.7	3.2	0.7
Tsunami siren	33.3	12.2	18.5	17.0
Shout of municipality officials	0.0	0.7	0.0	1.4
Shout of community leaders	3.9	0.0	0.4	0.0
Mobile phone, SMS etc.	12.7	12.2	14.2	11.6
Shout of family or neighbor	39.2	59.3	45.2	44.2
Others	5.9	5.1	6.8	6.8

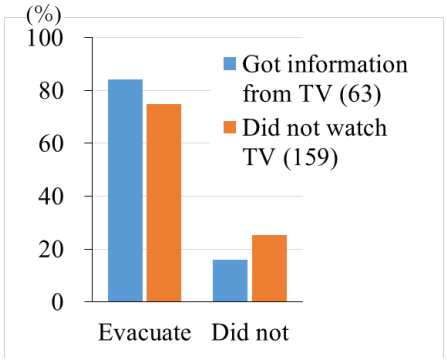

Fig. 5 – TV effect on evacuation or not

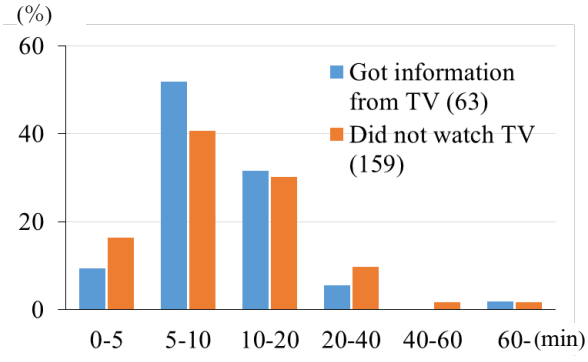

Fig. 6 – TV effect on evacuation start time

Table 6 – Evacuation rates by zone and gender

	Male					Female				
	A	B	C	D	E	A	B	C	D	E
Evacuated toward inland (%)	64	51	53	45	52	64	71	65	67	68
Evacuated to large and building (%)	9	4	4	4	0	19	3	3	6	0
Evacuated to mosque (%)	16	5	16	6	20	9	5	14	8	12
Subtotal of "evacuated" (%)	89	60	73	54	72	91	80	82	81	80
Moved to upper floor of his/her house (%)	2	2	3	2	4	0	2	2	2	0
Moved to upper floor of a nearby building (%)	0	0	3	1	0	0	2	2	6	0
Thought to be in safe place (%)	0	9	8	13	4	0	3	4	3	4
Did not move at all (%)	2	10	5	4	4	2	5	2	0	4
Went out of building but stayed there (%)	7	19	8	25	16	6	9	9	8	12
Total number (persons)	*55*	*177*	*277*	*83*	*25*	*47*	*118*	*194*	*64*	*25*

large buildings and mosques in the neighborhood. On the other hand, the rate of car evacuation in Zone C was large. This suggests that a relatively high proportion of people in Zone C owned a car or needed a car for their occupations. The ride rate per motorcycle was 1.6. The reason why so many evacuees used motorcycles seemed to be as follows. The distance from the center of Banda Aceh to the nearest hill was several kilometers, motorcycles were a daily means of transportation and one family owned 1.8 motorcycles on average. Parents and two children could ride one motorcycle if needed, and a whole family could ride and escape if they used a sidecar as seen in Photo 1.

3.7 Start time and required time for evacuation

The evacuation start times for each transportation method are shown in Fig. 7. There was no significant difference between the evacuation start times of motorcycles and cars, but those for pedestrians were late. This suggests that pedestrians were able to reach a nearby evacuation site in a short time, or that their starts were delayed for some reasons and congestions on roads had already begun so they chose to evacuate on foot.

In the 2012 earthquake, no tsunami reached to Banda Aceh, so 14% of residents quit evacuation at some point. 38% of these were on-foot evacuees, which is a relatively high rate. If this was because they could not find any suitable evacuation destination nearby and so had to give up, it would be a serious issue.

Fig. 8 shows the cumulative percentage of persons who had evacuated by the time shown in the lateral axis. Zone D is almost the same as zone C so is omitted, and zone E is also omitted because the number of data is small. Evacuation starting from Zone A, which was closest to the coast, was completed relatively quickly. This may have been partly because there were tsunami evacuation towers nearby and

Table 7 – Transportation method

	A	B	C	D	E
On foot (%)	16	6	15	13	5
Bycycle (%)	3	2	2	0	3
Motocycle (%)	71	82	67	75	84
Car (%)	9	9	16	12	8
Total number	*91*	*204*	*359*	*99*	*38*

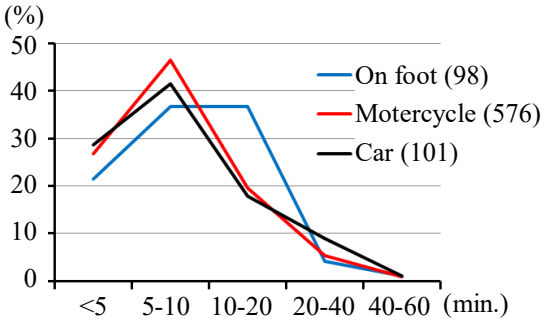

Fig. 7 – Evacuation start time vs. Transportation method

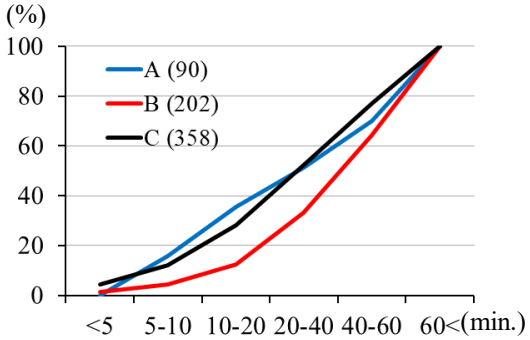

Fig. 8 – Cumulative number of people who completed evacuation vs. Zone

that many residents started evacuation early because of their awareness of the high risk. However, there were no suitable evacuation facilities in Zone B, so many people tried to escape to inland and were thus affected by traffic congestion. There were a large mosque and large buildings in Zone C, and additionally it was easier to escape to inland from this zone than from Zone B.

Fig. 9 shows the relationship between the evacuation destination and the cumulative number of persons who completed evacuation. The vertical axis is percentage and the lateral axis is required time. The time required for 80% of residents to reach their destination was 20 minutes for mosques or large buildings (including tsunami evacuation towers), and 60 minutes for inland. Many of the motorcycle evacuees and car evacuees chose inland as their destination, and consequently most of them encountered traffic congestions and took several times longer than usual to get there.

Fig. 10 shows the effect on evacuation start time people returning home or picking up family who were not at home. The difference between evacuation start times of those who started evacuation directly from home and those who started evacuation after returning home was about 10 minutes. On the other hand, there was no delay for the case of picking up family. In Banda Aceh, elementary and junior high school classes generally end in the morning. The quake occurred at 15:38, so the children who weren't around their homes probably were in an after school study place or a sports center or a game center. Most of these facilities were located in C and D Zones. Many parents seemed to pick up their children on the way of their evacuation destination.

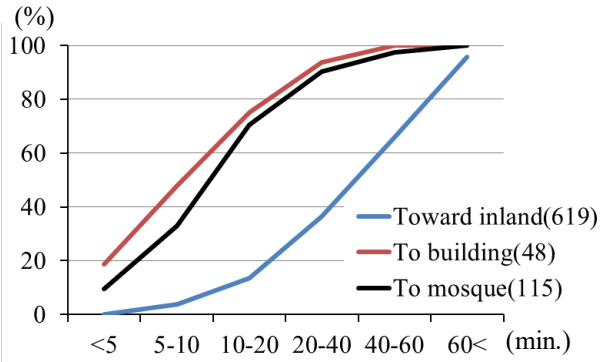

Fig. 9 – Cumulative number of residents who completed evacuation vs. destination

3.8 Change of evacuation route and destination

Table 8 shows that the closer the coast, the more difficult to reach the destination. In total, 59% of residents arrived at their destination without changing their intended route, but it was less in zones A and B than in other zones. One third of the residents in zones A and B changed their evacuation routes or destinations. Paying attention to the item "I reached the destination but changed the route due to traffic congestion", it can be seen that there was a level difference between zones A, B and C and zones D and E. Evacuees seemed to encounter difficulties in crossing the arterial road between zone C and zone D.

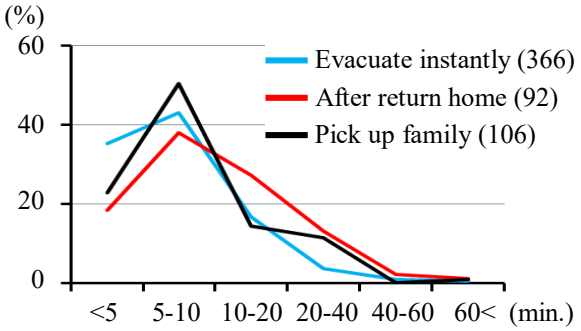

Fig. 10 – Affect of return home or pick up family

Table 8 – Change of evacuation route and destination

	A	B	C	D	E	Sum
Reached destination using intended route (%)	53	52	60	69	71	59
Reached destination, but changed route because of traffic jams (%)	24	26	24	13	16	23
Changed destination because of traffic jams (%)	11	5	4	3	3	5
Could not reach any destination because of traffic jams (%)	1	1	2	4	3	2
Started evacuation having no clear destination (%)	10	15	9	10	8	11
Quit evacuation on way because tsunami seemed not to come (%)	0	1	1	1	0	1
Total number	*90*	*203*	*359*	*99*	*38*	*789*

4. Analysis of Evacuation Routes by Animation

In the interview survey, 786 residents answered the questions concerning their evacuation routes and approximate evacuation times. The data was made into a moving picture by GIS and analyzed. The analysis procedure was as follows.

(1) Each evacuee was asked about his/her starting and ending points, average three intermediate passage points, approximate transit times, whether there was traffic congestion and whether or not they stopped by. Stop by was defined here to include stopping by to pick up children who had been out at the time of the earthquake, or stopping by a house of relatives or friends, or starting evacuation after returning home. In plotting the route by GIS, the shortest route between the passing points was analyzed and plotted.

(2) It was assumed that all roads could be used because the shaking caused almost no damage to the structures.

(3) Some roads in the downtown are restricted to one-way traffic. There are strong median strips on the main roads, and places where cars and motorcycles can make U-turns are limited. We don't know what would happen if a tsunami actually came and caused panic, but it was said that the traffic rules were followed during the evacuation turmoil following the 2012 earthquake. Therefore, in plotting the evacuation routes, motorcycles and cars were assumed to adhere to these traffic regulations and lanes.

(4) Pedestrians were not subject to these restrictions, so they were assumed to go anywhere as long as the roads were connected.

(5) There were a few intersections with traffic signals, which did not work due to the power outage, but no road closure measures were taken.

Figs. 11 and 12 show the captured images from the moving picture 10 minutes and 40 minutes after the earthquake. After only 10 minutes, there were congestions near the intersections where the branch road connected to the main arterial road. People also gathered around the Great Mosque, which was the most religious place in Banda Aceh. Forty minutes later, many evacuees were on the road and going inland. The road capacity heading inland decreased gradually, hence causing congestion. In addition, the evacuees who judged that they had reached safe places stopped their motorcycles or cars on the roadside, which reduced the effective width of the road and increased traffic congestion. It can be seen that the intersection where the traffic was heavy and traffic jams occurred in daily life had become a starting point of the traffic congestion. The non-operation of the traffic signals must have accelerated the congestion.

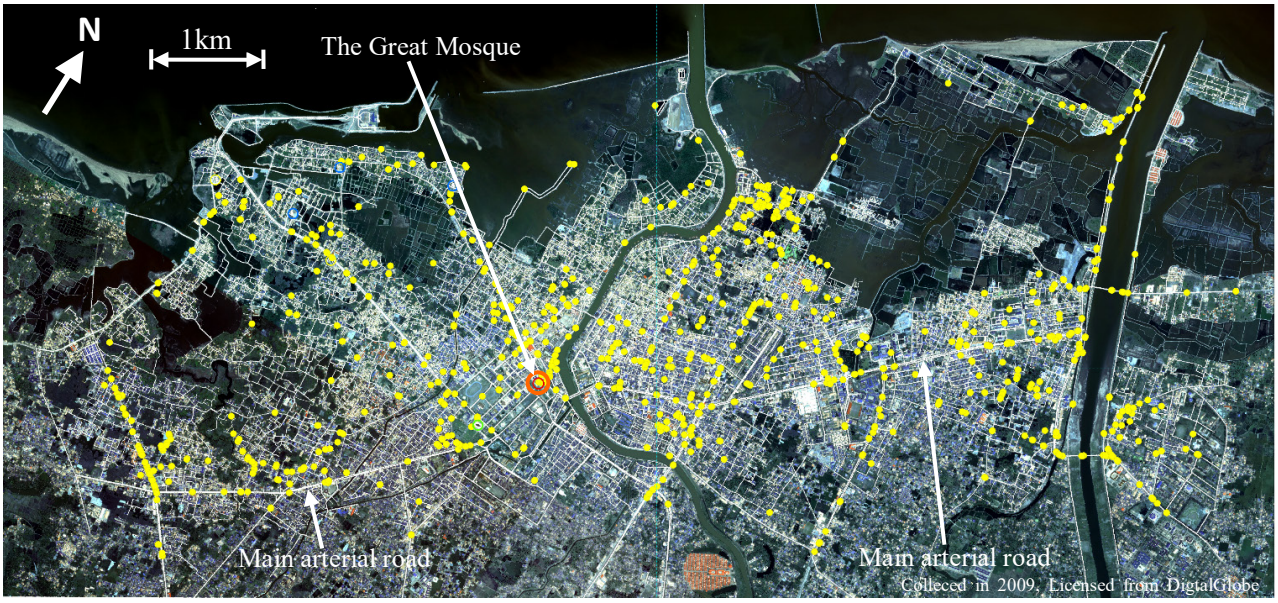

Fig. 11 – Location of evacuees 10 minuntes after earthquake

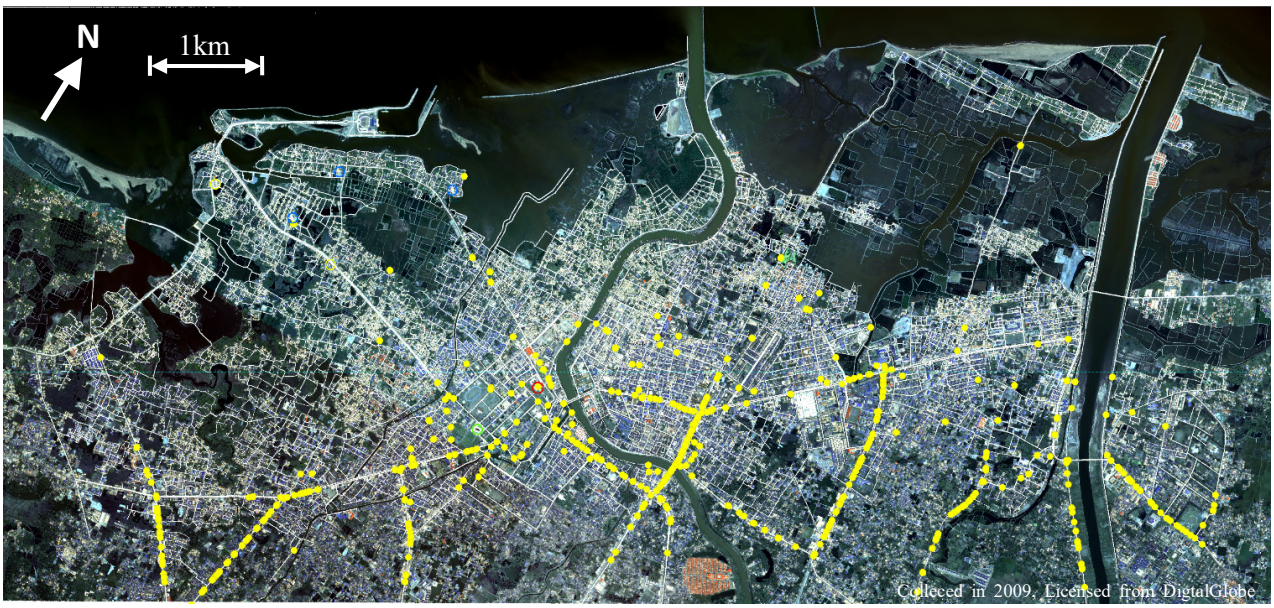

Fig. 12 – Location of evacuees 40 minuntes after earthquake

Table 9 – Increase of evacuation distance when not taking shortest route for motorcycle and car evacuation

Comparison among combinations of stopped by or not, changed route or not and changed destination or not	Number of evacuees who did not follow shortest route	Ratio to all evacuees	Average evacuation distance	Increase ratio of distance
(1) No stop by and no route change	151	0.55	3,769	1.18
(2) No stop by and route change	76	0.63	3,922	1.22
(3) No stop by and change destination	11	0.73	4,246	1.29
(4) Stop by and no route change	78	0.66	3,925	1.24
(5) Stop by and route change	32	0.73	3,914	1.27
(6) Stop by in and change destination	11	0.58	4,293	1.22

Evacuees did not always evacuate to their destination by the shortest route. Therefore, the evacuation distances of the six cases, which were combinations of stop by or not, change route or not and change destination or not, were analyzed and compared with the distance traveled if the evacuee had taken the shortest route. Table 9 shows the results. It was found that two-thirds of the evacuees did not follow the shortest route, and evacuation distances were about 20% longer than necessary, even without stop by. If they did stop by, the increases tended to be large. Detailed analysis of pedestrians was not possible due to the small number of samples.

Fig. 13 shows a typical example of a case where the difference between the actual evacuation route and the shortest route was large. Here, the motorcycle or car evacuation cases are picked up. ① to ⑤ indicate the start and end points in pairs. The yellow line is the actual evacuation route, the blue line is the shortest route, and their overlapping part is overwritten with the yellow line. They are all the motorcycle or car evacuation cases. In the case of ① and ③, the evacuees probably chose the routes that could avoid the traffic congestion because they knew where traffic jams were likely. In the case of ②, ④ and ⑤, the evacuees probably chose the everyday use roads that were easy to drive.

As a considerable number of evacuees did not choose the shortest route, the algorithm for an evacuation simulation using the multi-agent method [7] should consider these route selection tendencies.

Fig. 13 – Typical exsamples of difference between actual evacuation route and shortest route

5. Conclusions

(1) After the Mw 8.6 earthquake of April 11, 2012, more than 100,000 residents of Banda Aceh desperately evacuated in fear of a tsunami. Fortunately, no large tsunami occurred because the source fault was a strike-slip type. Therefore, this evacuation turmoil can be considered to be a valuable experience of a full-scale no-notice test to determine the evacuation potential of Banda Aceh and its residents.

(2) Most residents evacuated because of the shaking of the earthquake. In Banda Aceh, the tsunami warning issued by BMKG was not transmitted effectively, so residents relied on their own judgement and uncertain oral information. It is necessary to provide an effective means of transmitting a tsunami warning to residents, and to train them how to respond to it.

(3) Many residents tried to escape to inland using motorcycles and cars even if it took more than an hour. On the other hand, evacuees on foot tended to head to a nearby mosque or evacuation facility.

(4) A considerable number of evacuees stopped by during evacuation to pick up their children who were out at the time of the earthquake, or to visit close friends' and relatives' homes.

(5) The evacuation start times were in the order of car, motorcycle and on foot. Car users may have been in a hurry because it was obvious that they would encounter a traffic jam if they did not evacuate fast. It was presumed that evacuees on foot intended to go to a nearby evacuation place and thought they would have enough time, or they chose on foot evacuation to avoid the congestion as a result of their delay in starting.

(6) Some residents some distance from the coast tended not to evacuate. They might have been influenced by the success stories of survivors of the 2004 Indian Ocean tsunami, where, some people fled by motorcycle even after watching the tsunami and some people went up on the roofs of their house and had avoided the tsunami.

(7) The moving picture drawn showing the evacuation route and elapsed time obtained from the interviews made it possible to clarify where traffic jams occurred. An arterial road runs through Banda Aceh between the coast side and the inland side, and in relatively early hours after the earthquake, traffic congestions occurred in the coast side area and the intersection with the arterial road. In the later hours, there was traffic congestion on the road going inland from the arterial road. The number of roads heading inland gradually aggregated and the overall road capacity decreased. Moreover, a considerable number of people who thought

they had arrived in a safe area might have parked their motorcycles or cars on the roadside, thereby reducing the effective road width.

(8) Approximately two-thirds of residents who evacuated by motorcycle or car tended not to choose the shortest route, but a route that was easy for them or might avoid the intersection where traffic jams were expected. This tendency should be considered when constructing evacuation simulation software using the multi-agent method.

(9) Banda Aceh City Office is working to improve congested intersections and to improve inland roads. The busiest intersection at the time of this survey has already been overpassed. However, the number of car users is increasing and road network improvement is still urgently needed. The findings of this study are expected to be utilized in the planning.

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