Case ID: 081010-01

Accident Narrative

The bus with 48 passengers started the trip at about 19:00 from Khon Kaen. At about midnight the bus was travelling across a mountainous area between Nakhon Ratchasima and Prachinburi (**Figure 3-1**). On a downhill section between km 42+000 to km 47+500, the driver found a malfunction of the braking system and tried to slow the vehicle down, as reported by the bus staff. At km 44+800, while traveling on a down slope the driver decided to enter an emergency exit ramp in order to stop the bus. The speed of the bus, however, was still considerably high and it failed to stop on the ramp. The bus then went over beyond the emergency ramp and plunged into a deep embankment, crushed to ground and stopped on its right side. In total, 21 persons including the driver were found dead while 17 and 10 persons suffered serious and slight injuries, respectively.

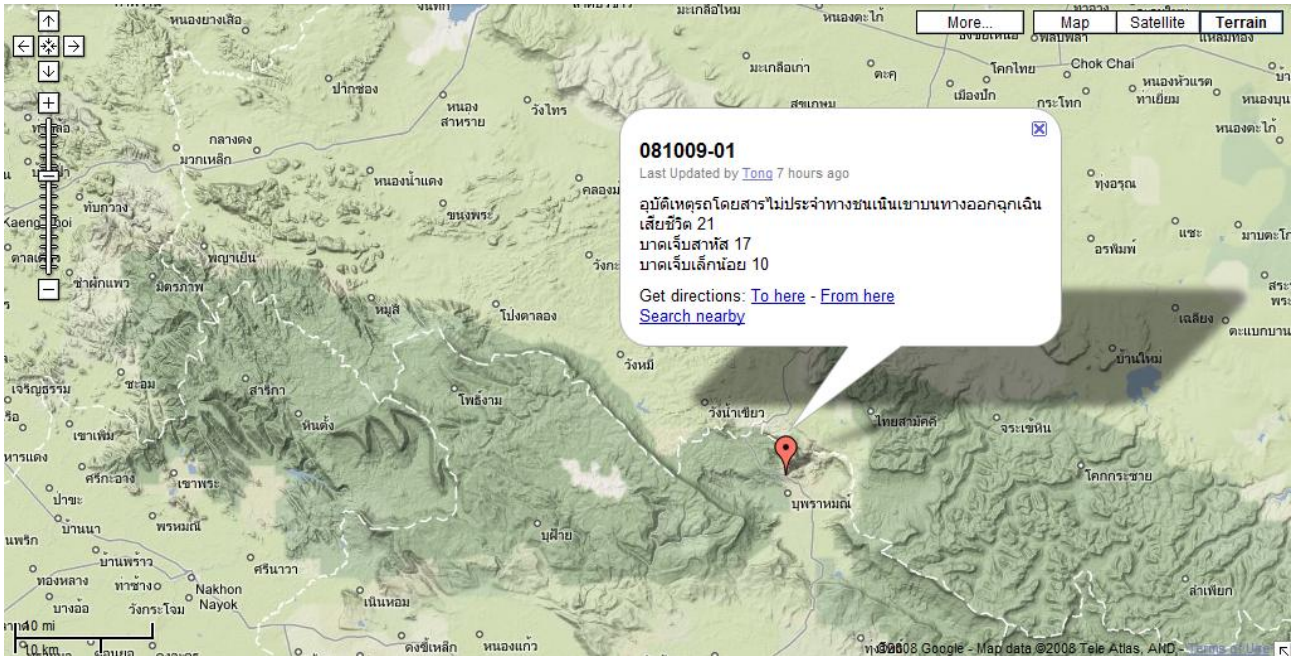


Figure 3-1: Site of the Bus Crash on a Mountainous Road between Nakhon Ratchasima and Prachinburi

From 48 occupants in total, there were 44 university students, one driver and three bus staff. The trip started at 19:00 on 9 September 2008 from Khon Kaen (A). The bus stopped at Tha Pra (B) and Ban Phai (F) at about 19:30. Then, it turned right to Highway No.229, to pick up more passengers at Mancha Khiri (D) and Chonnabot (E) at 22:00 and 22:10, respectively and returned to Bang Phai (F) at about 22:30 to refill the fuel. After all passengers were on board, the bus moved forward to Nakhon Ratchasima (G), and turned left to Highway No.304 the last stop before approaching the hilly terrain during the night.

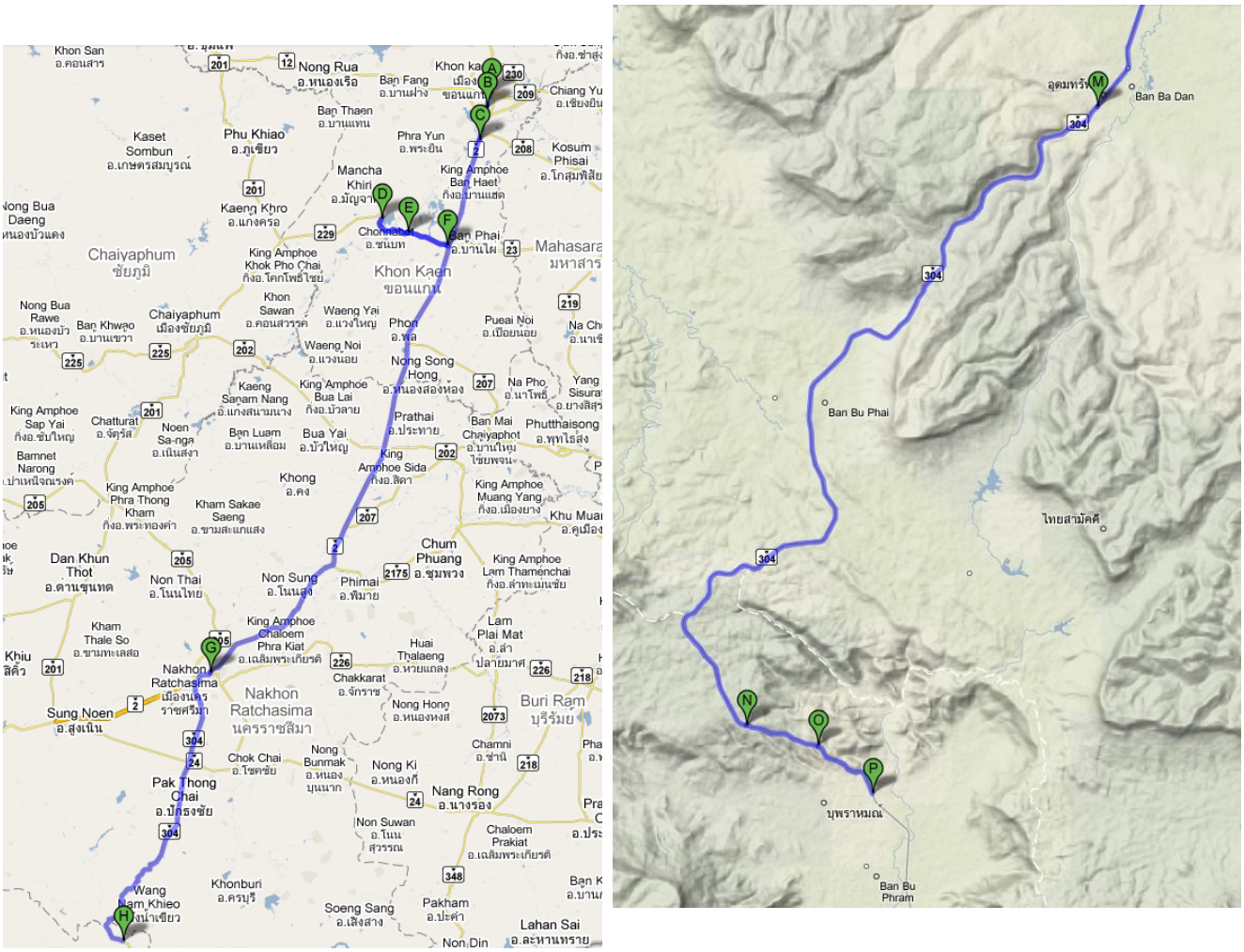


Figure 3-2: Bus Route

On the mountainous area between KM.78+00 (M) and 47+500 (N) (kilometer post started from Prachinburi), the bus staff mentioned that the bus could be operated smoothly. He did not find anything unusual during the journey. However, on the critical downhill connecting Thap Lan National Park and Khao Yai National Park starting from KM.47+500, the driver discussed with him that he found some problem while applying the brake. He could not reduce speed as usual. When the bus arrived at KM.44+800 (O), the driver decided to approach the 75 m. Emergency Exit Ramp to stop the bus. However, the bus did not stop immediately; instead it kept moving at high speed until reaching the top of the ramp. Then, it suddenly fell into the hillock front first, and stopped on its right side. 21 passengers were killed, while another 17 and 10 suffered serious and slight injuries respectively (**Table 3-1**).

Table 3-1: Summary of Occupant Injuries

Vehicle	Fatalities	Serious Injuries	Slight Injuries	No Injury
Bus	21	17	10	-

Vehicle Information

The double deck bus was a rental bus or non fixed route bus. The last vehicle registering was updated on 26 June 2007. The 8 cylinder Hino engine operated with a maximum of 320 hp. There were 3 axles and 8 wheels. The curb weight was 16,600 kg, and 2.4 x 12.0 x 4.2 m in width, length, and height.

A lower deck arranged into 5 parts including the driver cab, staff room, occupants compartment, luggage room and engine box. In the occupants compartment, a u-shape bench was installed with a table in the middle, close to another three sets of passenger seats at the end. On the upper deck, the seating configuration of the bus was arranged with 18 sets, ten on the right and eight on the left. There was a stair case between the fifth and the sixth row on the left. Each set connected between two seats except for the five seats on the last row. The passenger's seats were all individual but attached tightly as a pair. The seats were connected to the bus body by a pair of steel hooks, one attached to the floor while another one was attached to a side bar (**Figure 3-3**). However, only the last row and three sets on the lower deck the seats were installed on the bus floor by connected (connecting?) bolts. No seatbelt was installed on the seats.

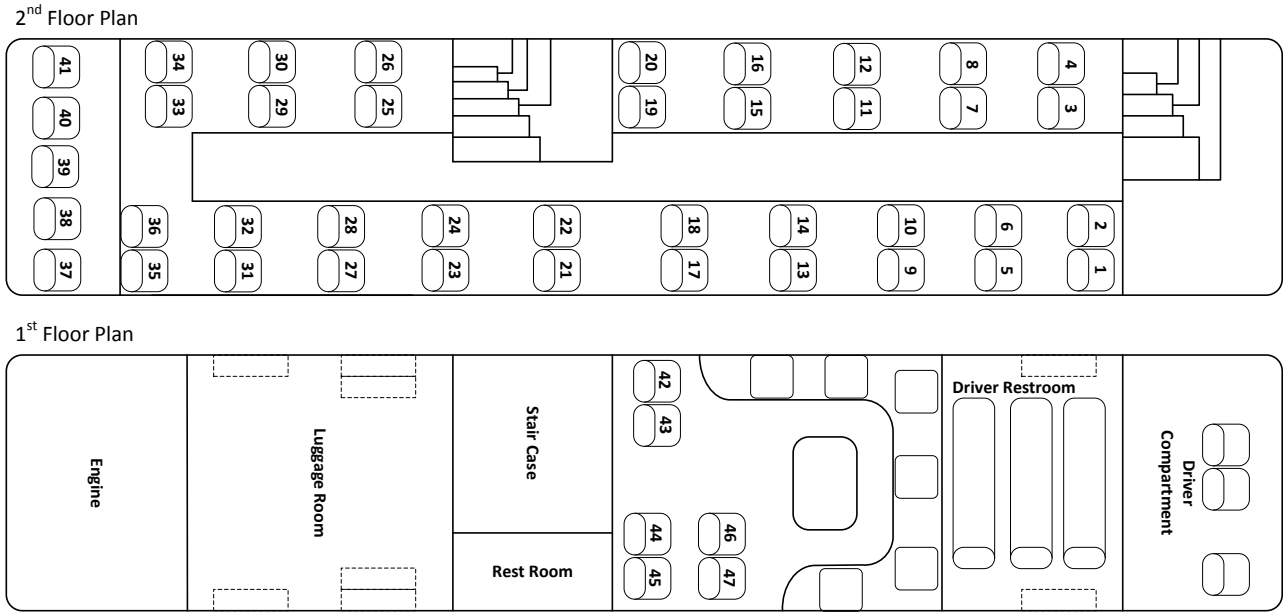


Figure 3-3: Seating Configuration

The suspension and brake system were inspected by a local bus mechanic and the forensic police on the day of the crash. The findings are summarized as follows,

1. Brake pads were in good condition. The spaces between pad and wheel were normal. Only at the middle axle the space was bigger than the other wheels, about 2 mm (**Figure 3-4**).
2. Steering rod was damaged due to the crash.
3. The driving gear was in the 3rd position.
4. Before this trip, two sets of air suspension were replaced.

Figure 3-4: Suspension and Brake System

The bus was deformed entirely on the front part due to the impact with a hillock. The driver compartment starting from the A-pillar intruded into the bus staff room and occupants

compartment. The driver and passengers' doors and console were crushed. The front axle was also bent. However, the damage on the roof as seen on the photo occurred during the post crash evacuation.

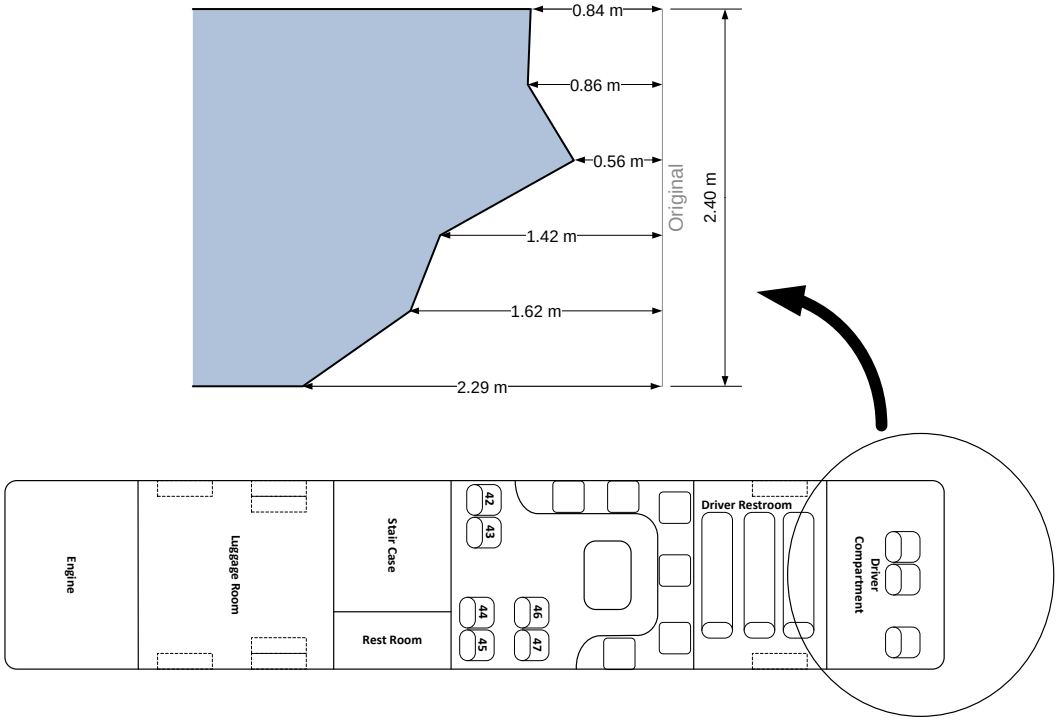
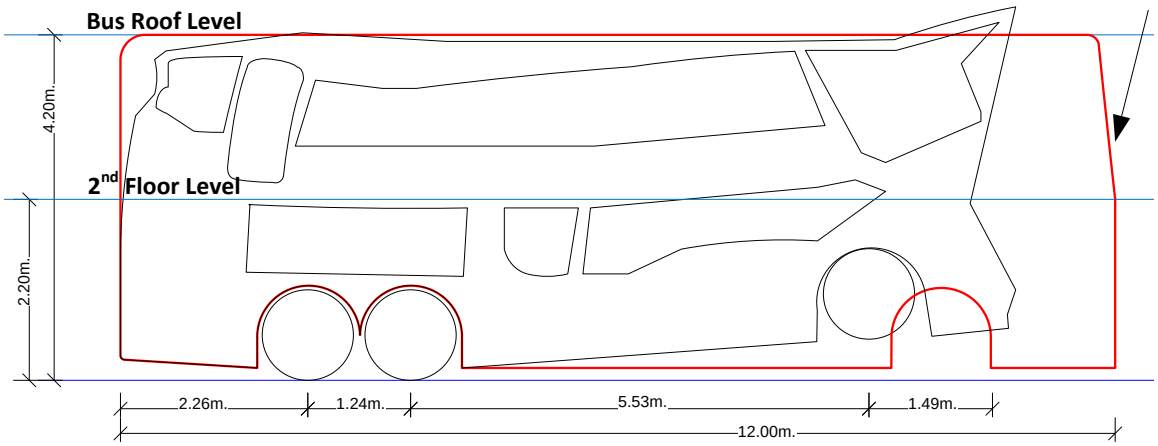
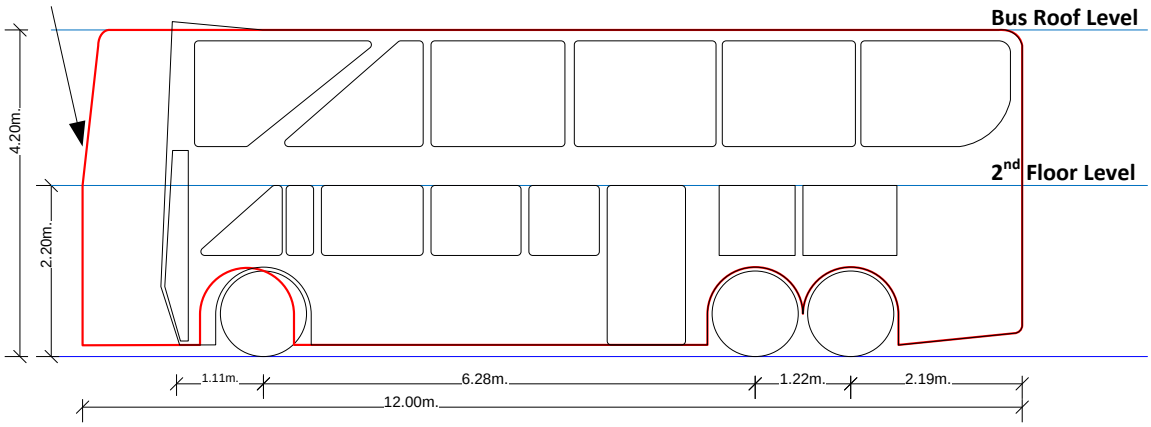


Figure 3-5: Frontal Deformation

Figure 3-6: Damaged Bus



Right Side



Left Side

Figure 3-7: Side Dimension

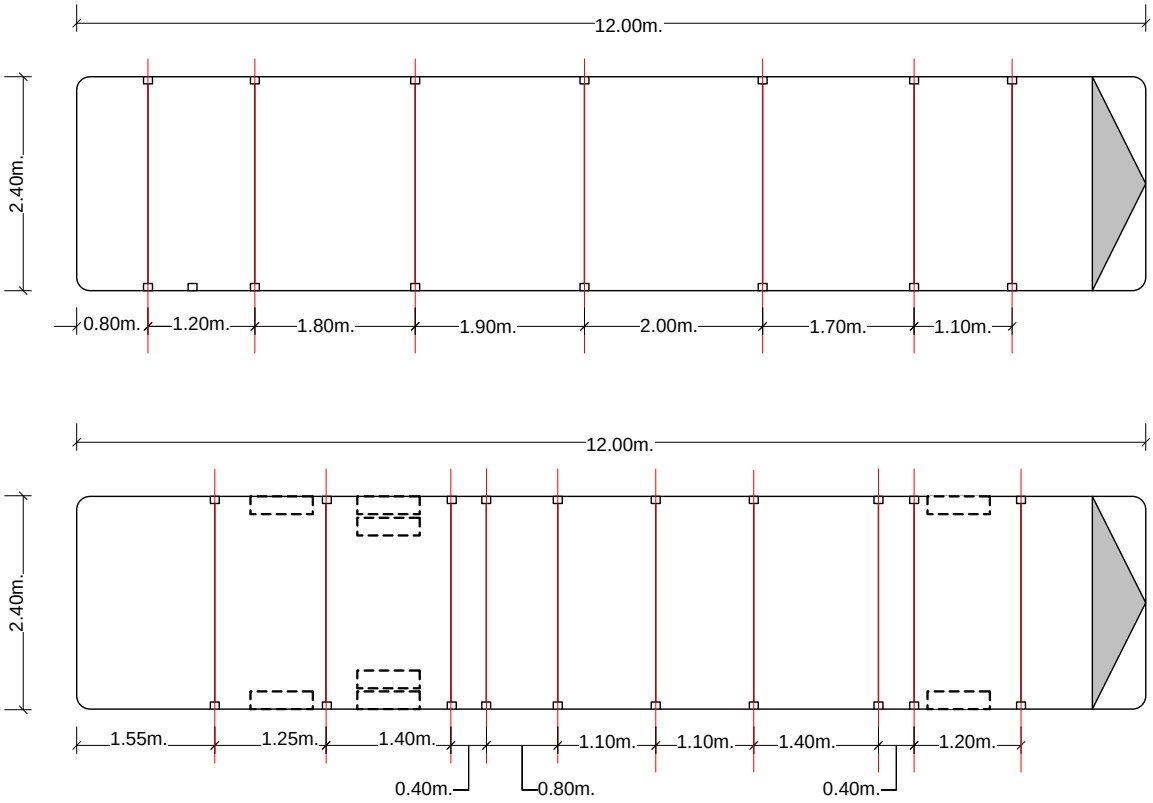


Figure 3-8: Top View Dimension

Due to major damage to the front part, the intrusion extended to the occupants compartment on the upper deck. The first and second pillars were displaced while all of the passenger seats were separated from their original position. **Figure 3-9** presents the comparison before and after the crash. **Figure 3-10** and **Figure 3-11** show the seating dimension and the hook connecting the seats and the bus body as mentioned.

Figure 3-9: Seating Configuration Before and After Crash

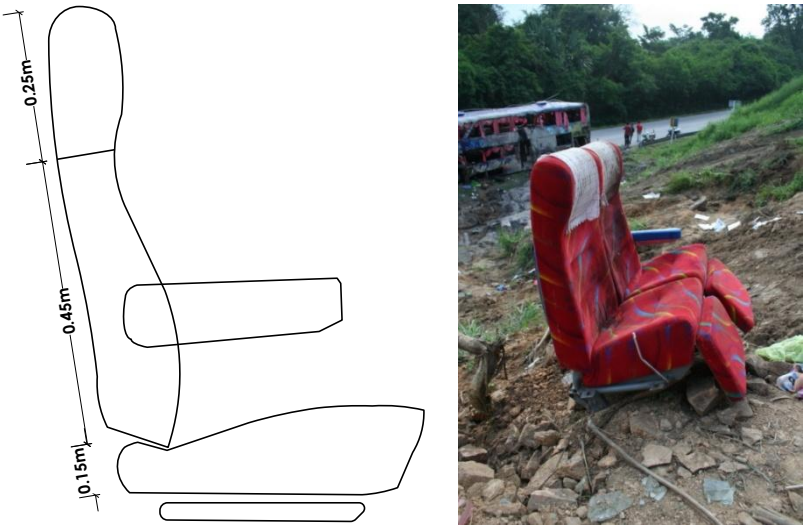


Figure 3-10: Seating Dimension

Figure 3-11: Seating Connection

Three seats on the lower deck (Seat No.42-47) were installed to the floor with connecting bolts. There was only one set in place, while the other two were missing. **Figure 3-12** shows that the bolts were still firmly screwed to the steel structure.

Figure 3-12: Lower Deck Seat

Driver Information

The driver was a 43 year old male. He was a native of Pichit but lived in Khon Kaen. Back in 1987, he was granted a Driver License Class II, license to drive cargo trucks or buses carrying less than 20-passenger, with more than 3,500 kg total in weight. The existing license has been validated for the period from 16 May 2007 until 15 May 2010.

, The driver started his carrier in the bus industry when he was young. He worked at Mo Chit, National bus station in Bangkok as a bus staff for number of years. After that, he became a driver for fixed routes and non-fixed routes and gathered over 20 years of experience according to his wife and co-workers. Before taking this trip, he had traveled to Southern provinces for military army reciprocation and returned to Khon Kaen on 8 October 2008.

The day before the trip, the driver and his staff repaired the air suspensions of the bus. They changed two out of four. His staff started driving the bus at the beginning of the trip, and they switched again after arriving in Ban Phai, about half an hour later. **Figure 3-13** shows the timeline of driving hours before the crash.

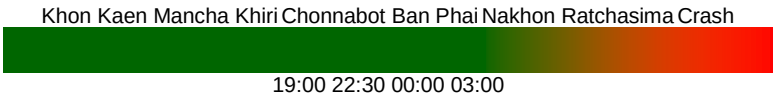


Figure 3-13: Driving Hour

Highway Information

Highway No.304 serves as a main Northeastern-Eastern corridor. The total length, from Nakhon Ratchasima to Chachoengsao, is about 242 km. It passes through the mountainous area connecting Wang Nam Khieo (Nakhon Ratchasima) and Nadi (Prachinburi).

In the mountainous area of the crash, there was a two lane undivided, asphaltic concrete road. The road is between Thap Lan National Park and Khao Yai National Park. The downhill section starts from KM.47+500 with approximately 6% grade. At KM.44+800, where the crash occurred, it composes of a 242.837 m. radius curve with a total length of 124.682 m. In addition, at the starting point of the curve, an emergency exit ramp is constructed with a 75 m. long embankment and a 6.7% uphill grade.

Figure 3-14: Road and Environment at the crash scene

The sight distance during nighttime is limited by the lack of a road lighting system. Nevertheless, delineators are installed along the traveling way on the guiding posts, barriers or signs in order to increase the visibility during darkness (**Figure 3-15**).

Figure 3-15: Driver's View on the Emergency Exit Ramp

The traffic control devices installed before approaching the crash location are summarized as follow;

500 m	"Emergency Exit 500 m Ahead" Warning Sign
	"Downhill" and "Use Low Gear" Warning Sign
300 m	"Hazardous Curve Ahead, High Crashes Location" Warning Sign
	Emergency Exit Warning Sign
	Right Curve Warning Sign
	Blinking Amber Lighting
200 m	"Emergency Exit 200 m Ahead" Warning Sign

Crash Statistic

The 11 years crash statistic (1997-2007) of Highway No.304 between KM.78+000 and 42+000 is shown in **Table 3-2**. There were 470 crashes in total, with 169 fatalities and 979 injuries. Single vehicle crashes shared about 60% of the total crashes while another 40% were multiple vehicle crashes. In addition, considering only single vehicle crashes, there were up to 588 trucks or 81%, involved in the crashes.

Table 3-2: 11 Years Crash Statistic on Highway No.304 (km.78+000 to km.42+000)

Crashes	**470**
Single Vehicles	280
Multiple Vehicles	190
Fatalities	**169**
Male	118
Female	51
Injuries	**979**
Male	603
Female	376

Vehicles	**730**	
Motorcycles	32	(4%)
Motortricycles	1	(0.1%)
Passenger Car	28	(4%)
Buses	53	(7%)
Trucks	588	(81%)
Others	28	(4%)

Source: Bureau of Highway Safety, Department of Highways

Focusing more specifically on the downhill section between KM.47+500 and KM.42+000, the proportion of crashes on this 5.5 km section covered more than 70% of the total mountainous section. The trucks represent the highest share of vehicle types involved in

crashes (84%) as shown in **Table 3-3**. **Table 3-4** lists a high record of victims of crashes along this mountainous section.

Table 3-3: 11 Years Crash Statistic on Highway No.304 (km.47+500 to km.42+000)

Crashes	**330**
Single Vehicles	196
Multiple Vehicle	134
Fatalities	**110**
Males	81
Females	29
Injuries	**694**
Males	400
Females	294

Vehicles	**525**	
Motorcycles	11	(2%)
Motortricycles	-	-
Passenger Cars	14	(3%)
Buses	36	(7%)
Trucks	443	(84%)
Others	21	(4%)

Source: Bureau of Highway Safety, Department of Highways

Table 3-4: High Number of Victims Crashes

Date	Time	Km.	Vehicle	Crash Type	Fatality	Injury
21/3/1997	16:00	44+200	Truck	Hit object	3	-
21/3/1997	15:30	43+000	Truck	Rollover/Run Off	3	-
7/4/1997	4:00	45+000	Truck and Trailer	Car Collision	2	10
7/4/1997	4:00	44+660	Truck and Trailer	Car Collision	2	1
17/6/1997	5:00	57+500	Bus and Trailer	Car Collision	4	-
28/9/1997	2:00	63+875	Truck	Hit object	11	44
28/9/1997	2:20	64+500	Bus	Rollover/Run Off	6	10
3/12/1997	1:30	47+500	6 Cars	Car Collision	3	30
3/12/1997	1:30	47+000	4 Cars	Car Collision	3	10
1/6/1998	2:00	46+000	Bus	Rollover/Run Off	3	38
21/2/2000	18:10	44+225	Truck and Trailer	Car Collision	7	-
17/4/2000	19:00	44+212	Bus	Rollover/Run Off	5	33
17/2/2001	8:30	44+250	Trailer	Rollover/Run Off	5	-
13/4/2002	7:00	63+500	Bus	Rollover/Run Off	7	6
16/4/2002	23:30	44+200	3 Cars	Car Collision	2	14
13/1/2004	0:30	71+100	Bus and Trailer	Car Collision	7	8
10/10/2004	18:15	44+300	Trailer	Hit object	3	-
16/4/2005	1:15	43+300	Bus	Rollover/Run Off	2	35
16/5/2005	0:30	43+000	5 Cars	Car Collision	5	49
10/4/2007	2:00	50+063	Bus	Rollover/Run Off	7	30
10/10/2008	3:00	44+800	Bus	Rollover/Run Off	21	27

Source: Bureau of Highway Safety, Department of Highways

Physical Evidence

After examining the crash scene starting from the previous curve to the crash scene, no distinct marks showing the bus movement, evasive maneuver or tire marks, prior to approaching the emergency exit were found. The condition of the ramp, however, was modified during the time the TARC team performed its investigation. Therefore, some information of the ramp relied on the photos from local news reporters. As clearly seen from **Figure 3-16**, there were no sliding wheel tracks printed on the ramp, even between the wheels and grass nearby.

Figure 3-16: Ramp Condition after Crash
Courtesy of Mr. Pairoj Kled-ngoen

After the bus reached the top of the hill, it suddenly fell into a 24% downhill hillock and hit the embankment with its front, considered as Point of Impact (POI). The bus overturned and kept moving for some distance and stopped on its left side (**Figure 3-17)**. The total distance the bus moved from the top to POR was about 40 m. (inclined distance) as shown in the moving diagram in **Figure 3-18**.

Figure 3-17: Point of Rest
Courtesy of Mr.Pairoj Kled-ngoen

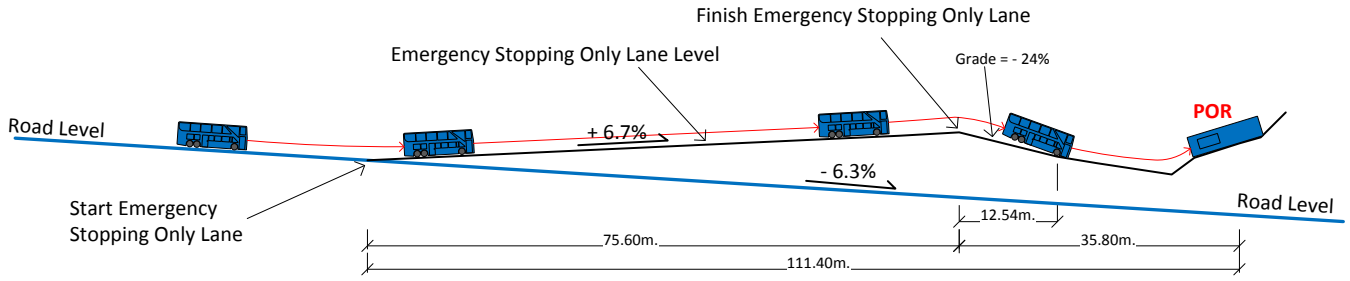


Figure 3-18: Diagram showing the bus movement

Injuries Information

There were 21 fatalities, 17 serious injuries and 10 slight injuries reported from this crash. **Figure 3-19** shows the diagram of seating position of the occupants by severities. The red shows fatalities, orange the serious injuries and yellow the slight injuries. Unspecified occupants are shown in blue. The detail of injuries information is shown in **Table 3-5**.

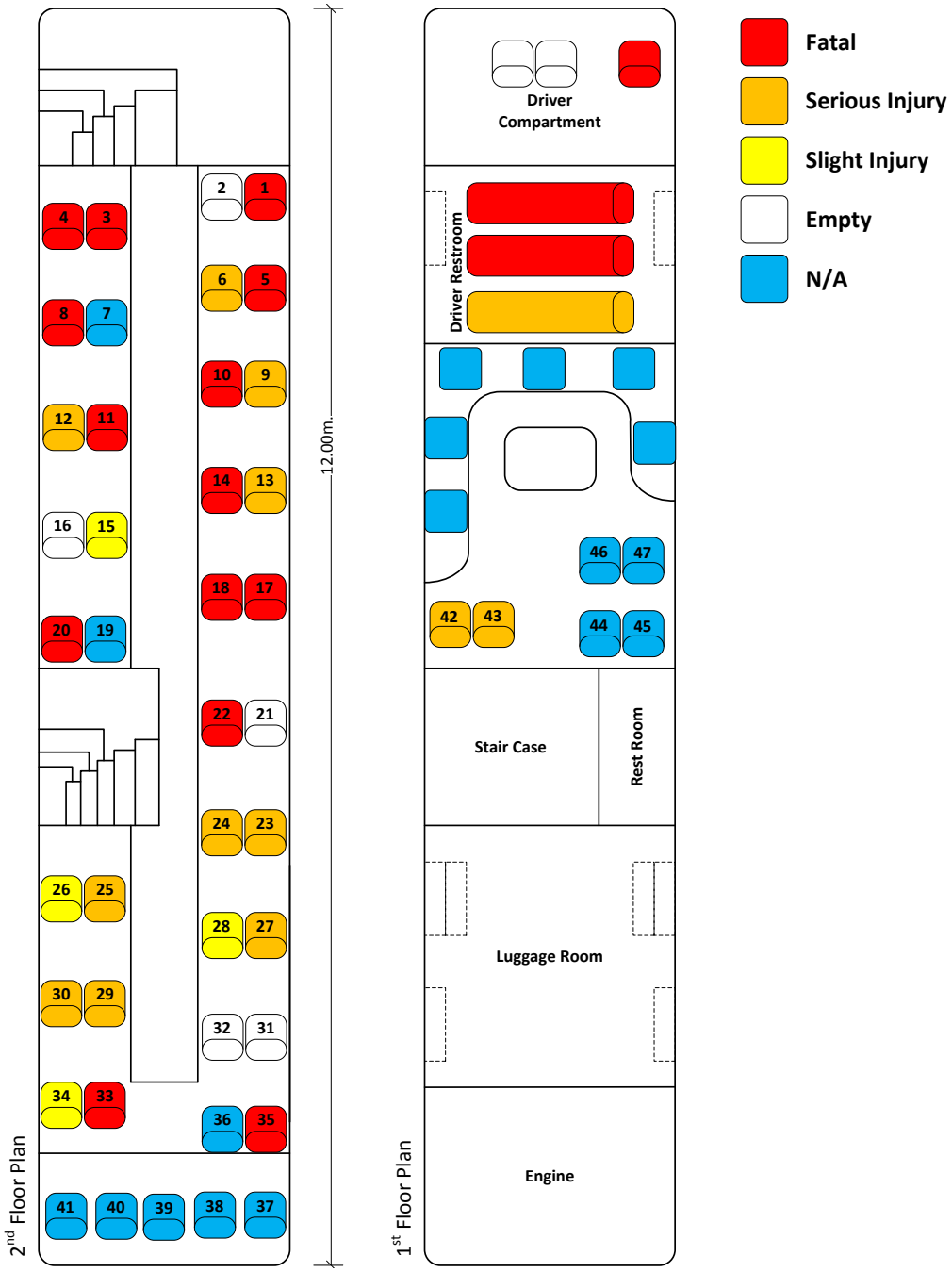


Figure 3-19: Seating Positions of Occupants inside the Bus

Table 3-5: Summary of Occupant Injuries

Person	Gender	Age	Level of Injury	Injury	ICD 10
38 (Driver)	Male	43	Fatal	Traumatic intracerebral haemorrhage	S06.3
28	Male	45	Fatal	Traumatic intracerebral haemorrhage	S06.3
29	Male	45	Fatal	Traumatic intracerebral haemorrhage	S06.3
30	Male	52	Fatal	Fracture of femur	S72.9
31	Male	55	Fatal	Traumatic intracerebral haemorrhage	S06.3
32	Male	N/A	Fatal	Fracture of base of skull	S02.1
33	Male	50	Fatal	Fracture of neck at spine	S12.9
34	Male	24	Fatal	Traumatic haemopneumothorax	S27.2
35	Male	26	Fatal	Fracture of neck	S12.9
36	Female	22	Fatal	Traumatic intracerebral haemorrhage	S06.3
37	Male	37	Fatal	Injuries of lung	S27.3
39	Male	40	Fatal	Fracture of femur	S72.9
40	Male	55	Fatal	Injuries of lung	S27.3
41	Female	47	Fatal	Injuries of lung	S27.3
42	Male	N/A	Fatal	Injuries of lung	S27.3
43	Female	39	Fatal	Traumatic intracerebral haemorrhage	S06.3
44	Male	58	Fatal	Traumatic intracerebral haemorrhage	S06.3
45	Male	28	Fatal	Traumatic intracerebral haemorrhage	S06.3
46	Male	47	Fatal	Traumatic intracerebral haemorrhage	S06.3
47	Male	48	Fatal	Traumatic pneumothorax	S27.0
48	Male	N/A	Fatal	Fracture of neck	S12.9
1	Male	46	Serious	Open wound of knee	S81.8
				Fractures of ankle	S82.8
				Fracture of rib	S22.3
				Fracture of thoracic vertebra	S22.0
4	Male	21	Serious	Open wound of oral cavity	S01.5
				Open wound of lip	S01.5
				Injury to the hip	S79.9
5	Male	45	Serious	Fracture of upper limb	T10.0
				Injury to the hip	S79.9
7	Female	45	Serious	Injury to the thorax	S29.9
				Injury to the abdomen	S39.9
				Open wound of head	S01.8
				Open wound of lip	S00.5
8	Male	40	Serious	Open wound of forearm	S51.0
				Injury to the hip	S79.9
9	Female	35	Serious	Open wound of forehead	S01.8
				Open wound of wrist	S61.9
				Injury to the hip	S79.9
10	Male	27	Serious	Open wound of lower limb	T13.1
				Open wound of finger	S61.1
				Specified injuries of upper arm	S49.8
12	Male	25	Serious	Traumatic intracerebral haemorrhage	S06.3
13	Male	15	Serious	Traumatic intracerebral haemorrhage	S06.3
				Traumatic intracerebral haemorrhage	S06.3
				Contusion of eyeball	S05.1
				Superficial injury to the cheek	S00.8
				Multiple superficial injuries of body	T00.9
14	Male	35	Serious	Contusion of thorax	S20.2
				Open wound of ankle	S91.0
				Open wound of forehead	S01.8
				Open wound of chin	S01.8
				Superficial injury to the upper limb	T11.0
				Injuries of lung	S27.3
15	Male	45	Serious	Superficial injury to the upper limb	T11.0
				Fracture of lower limb	T12.0
				Open wound of forehead	S01.8
				Contusion of eyeball	S05.1
				Multiple fractures of ribs	S22.4
				Sprain and strain of hip	S73.1
16	Male	22	Serious	Injury to the muscle at shoulder	S46.9
				Superficial injuries of hip	S70.8
17	Male	28	Serious	Fracture of rib	S22.3
				Superficial injury to the face	S00.8
				Superficial injury to the face	S00.8
23	Male	30	Serious	Fracture of upper arm	S42.9
24	Male	N/A	Serious	N/A	N/A
18	Male	N/A	Serious	Fracture of c-spine	S22.0
26	Female	N/A	Serious	N/A	N/A
19	Male	N/A	Slight	Fracture of rib	S22.3

Table 3-35: Summary of Occupant Injuries (Cont.)

Person	Gender	Age	Level of Injury	Injury	ICD 10
20	Female	24	Slight	Open wound of upper limb	T11.1
				Open wound of hand	S61.8
				Injury to the hip	S79.9
21	Male	N/A	Slight	Fracture of rib	S22.3
22	Male	N/A	Slight	mildHI fx pelvis	S72.8
25	Male	N/A	Slight	N/A	N/A
27	Male	39	Slight	N/A	N/A
2	Male	35	Slight	Open wound of eyebrow	S01.8
				Open wound of eyebrow	S01.8
				Superficial injury to the lower limb	T13.0
3	Male	42	Slight	Superficial injury to the lower limb	T13.0
6	Male	24	Slight	Injury to the shoulder	S49.9
				Injury to the thorax	S29.9
11	Male	20	Slight	Superficial injuries of chest	S20.3
				Superficial injuries of lower leg	S80.8
				Superficial injuries of foot	S90.8

Accident Contributing Factors

Brake System on Downhill

Driving on a long distance of mountainous section requires high skills of driving maneuver, especially for heavy vehicles which are equipped with an air brake system. Generally, the mechanism of air brake system starts by taking filtered air from the atmosphere, compressing it, and keeping it in high-pressure reservoirs. When applying the brakes, this high pressure air is routed to the operating cylinders on the brakes, which actuate the braking hardware and slow the vehicle (Wikipedia, 2009). The air brake system used for heavy vehicles is separated into two parts, the supply system and the control system. While the engine is working, the compressed air is routed through the air compressor system and stored in the reservoir. When the driver presses on the brake pedal, the supply line from the trailer brake circuit receives air from the air tank. However, when applying the brakes more frequently, it is possible that the engine could not supply the compressed air into the tank as it used to and cause a shortage of air in the system. In this case, the bus traveled on the hilly section for about 30 km before the bus driver found the error in the brake system while on the downhill section. The driver controlled the bus using the lowest possible gear. The mechanical inspection showed that the driving gear was in the third position. Accordingly, all of braking pads were in good condition without burns from the scratching with the rotating wheels.

There is a possibility of air leaking. However, if detected by the valves, the entire supply system will be shut down automatically. The post investigation could not determine whether this former scenario took place since most of the system was destroyed in the crash.

In addition, there were no reports blaming the awareness of the driver. He was not found drowsy, under the influence of drug or alcohol or inattentive according to passengers and staff statements.

Emergency Exit

A speed-distance calculation was performed to determine the ability of the emergency ramp to reduce the speed. Fixing a coefficient of friction equal 0.6 on 6.7% grade uphill as measured from the scene; the speed drops only by 9-10 km/hr if entering a speed between 51-58 km/hr. The efficiency of the ramp is possibly reduced by the natural compaction of the gravel pavement over time. It was revealed from relevant agencies that this exit has been improved the roughness condition monthly. However, the soil was easily compacted again after pouring of the falling rain.

Seating Strengthening and Occupants Restraint System

People bouncing on each other and the seats detaching from their position caused harm to the occupants during the event of crash, according to victims statements. The crash consequences were reminiscent of another bus crash which happened on Highway No.304 in Doi Saket, Chiang Mai, where 17 passengers died. At that time, the seating on the upper deck detached from the body, as in this crash. It was documented that the fixing system was almost the same, where the hook fixed the seat on the bus body near the walkway, while another set of bolts was fixed into the sidebar. However, in Chiang Mai, the bus overturned more than 720 degrees, while the bus turned 90 degree after frontal impact in this crash. It was revealed from the bus manufacturer that this installation is preferred by the bus companies since it requires less time and power to rearrange the seating configuration compared to fixing the seat on the bus floor. This issue is still not addressed in the Land Traffic Act or Land Transport Act.

Figure 3-20: Detached Seats of the 19 January 2007 Bus Crash

Figure 3-21: Detached Seats of the 10 October 2008 Bus Crash