Questionnaire survey of the occupants of high-rise residential buildings in Sapporo after the 2018 Hokkaido Eastern Iburi Earthquake

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ABSTRACT
In this study, a resident questionnaire survey was conducted for three reinforced-concrete high-rise condominium buildings in Sapporo. All three were subjected to the 2018 Hokkaido Eastern Iburi Earthquake. Resident experiences of shaking and damage due to the earthquake, the seismic measures taken before and after the earthquake, and conditions during the long-term black out were evaluated by the survey. Resident anxiety and their difficulty in taking actions due to the shaking were relatively small, because the ground motions input to the buildings were not very large. The long-term power outage due to the earthquake had a great impact on the occupants. Particularly, the inability to use elevators caused a great inconvenience to the residents of higher floors, making it difficult for them to leave their dwelling units. Each of the three buildings was equipped with an emergency power supply; however, differences in the operation methods of these supplies affected the convenience of the occupants during the power outage. The inconvenience and anxiety caused by the shaking and the power outage left a strong impression on the residents. This may have resulted in motivation to make further earthquake preparations, such as stockpiling of flashlights, lanterns, food, and water, after the complex disaster.

1. Introduction
The 2018 Hokkaido Eastern Iburi Earthquake, the epicenter of which was in the central-eastern Iburi area of Hokkaido, Japan, occurred on 6 September 2018. The magnitude of this earthquake reported by the Japan Meteorological Agency (JMA) was $M_{JMA} = 6.7$, and the focal depth was 37 km (JMA 2018; Katsumata et al. 2019). During the earthquake, a JMA seismic intensity of 7, which is the maximum possible value, was recorded in the town of Atsuma near the epicenter (JMA 2018). (In this paper, every seismic intensity is reported according to the JMA scale.) This was the first time that a seismic intensity of 7 was observed in Hokkaido since the current JMA seismic intensity scale was applied. Also, a seismic intensity of 6 upper, which is the next-highest possible intensity, was observed in the towns of Atsuma, Mukawa, and Abira (JMA 2018).

In total, as reported by the Hokkaido Government (2019), a total of 44 people died due to the earthquake, which includes 3 deaths of disaster-related death. Around the mountain area near the epicenter, especially in Atsuma, simultaneous multiple slope failures occurred due to the strong shaking of the earthquake, resulting 36 fatalities in Atsuma (Cabinet Office, Government of Japan 2019; Yamagishi and Yamazaki 2018). As a result of the shaking from the earthquake, liquefaction occurred, resulting in damage to many residences (Takahashi and Kimura 2019). The number of damaged buildings due to the earthquake, including the effects of the strong shaking, slope failures, and liquefaction, was reported as follows (Hokkaido Government 2019): for dwellings, 479 completely destroyed, 1,736 half destroyed, and 22,741 partially damaged; and for non-residential buildings, 1,213 completely destroyed, 1,407 half destroyed, and 3,881 partially damaged. A coal electric power plant located in Atsuma suffered the strong shaking of the earthquake, resulting in shutdown of the plant; moreover, hydropower transmission lines were damaged due to the earthquake; and consequently a long-term massive blackout occurred in all of Hokkaido (Verification Committee for the Large-Scale Blackout Associated with the 2018 Hokkaido Eastern Iburi Earthquake 2018).

In other severe earthquakes recently occurring in Japan, notably the 2011 off the Pacific coast of Tohoku Earthquake and the 2016 Kumamoto Earthquake, post-earthquake questionnaire surveys were conducted for the occupants of high-rise residential buildings (Tamura et al. 2012; Hida and Nagano 2012; Architectural Institute of Japan 2013; Nagano et al. 2018). However, similar survey results have not been reported for the 2018 Hokkaido Eastern Iburi

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Earthquake. In the case of the 2018 Hokkaido Eastern Iburi Earthquake, the impact of the long-term blackout was very much larger, and it may have had a major effect on the occupants living in high-rise residential buildings. Therefore, it was considered meaningful to conduct a questionnaire survey for the residents of tall buildings and include questions on the effects of the blackout.

In the present study, a questionnaire survey was conducted for the occupants of three high-rise residential buildings whose superstructures are made of reinforced concrete (RC). All three are located in the city of Sapporo and were subjected to the 2018 Hokkaido Eastern Iburi Earthquake. The survey included questions on resident experiences of earthquake shaking, damage they observed, seismic countermeasures taken before and after the earthquake, and conditions during the long-term blackout. The survey was carried out around 2–3 months after the occurrence of the earthquake for two of the three residential buildings, while it was done around 7–8 months after the earthquake for the other building. In this paper, methods and results of the questionnaire survey are provided, including a discussion based on the survey results. In addition, this paper expands on a previous report (Horii and Shirai 2020) by adding new results and findings.

2. Survey methods

Sapporo is the governmental and economic center of Hokkaido, which is located in northern Japan. The epicenter of the earthquake was approximately 68 km away from JR Sapporo Station, which is the transportation center of Sapporo. Maps of the area around the epicenter of the 2018 Hokkaido Eastern Iburi Earthquake are shown in Figure 1. In the earthquake, the K-NET Sapporo seismic station (HKD180) recorded a peak ground acceleration of 1.43 m/s² in the N–S direction and 1.54 m/s² in the E–W direction. This station, located in Taihei, Kita Ward, Sapporo, is a strong motion observation point deployed and managed by the National Research Institute for Earth Science and Disaster Resilience. The metered seismic intensity at HKD180 was 5.1, corresponding to a seismic intensity of 5 upper. The observed acceleration waveforms for both the N–S and E–W directions are shown in Figure 2(a). The response acceleration, velocity, and displacement spectra with a damping factor of 5% for both the N–S and E–W directions are shown in Figure 2(b–d). In addition, a seismic intensity of 6 lower was observed in Motomachi, Higashi Ward, Sapporo. Finally, the long-period ground motion class of the earthquake evaluated in the central Ishikari region was reported as “Class 2” (JMA), which is the second-smallest class among the four classes.

In the present study, three residential high-rise buildings located in Sapporo were selected for the questionnaire survey. The reasons for targeting the high-rise buildings in Sapporo are as follows: In this earthquake, the areas where extremely strong shaking with a seismic intensity of 7 or 6 upper was observed were away from urban areas and no high-rise residential buildings have been built there; Sapporo is the city with the largest population in Hokkaido, and although the shaking in Sapporo was relatively small compared to the areas near the epicenter, the long-term blackout due to the earthquake would have significantly affected the residents of high-rise buildings, and this impact is also an important topic to be examined. Table 1 gives an overview of the three buildings, which are referred to as Buildings A, B, and C for anonymity. All three buildings are located within 5 km of JR Sapporo Station. The nearest K-NET observation point from the three buildings is the above-mentioned station HKD180, where a seismic intensity of 5 upper was

![Figure 1](image-url). Maps of the epicenter of the 2018 Hokkaido Eastern Iburi Earthquake (modified from the GSI Maps provided by the Geospatial Information Authority of Japan, with additional information): (a) wide area map; and (b) close-up map.
recorded. Observation points other than K-NET near the three buildings observed seismic intensities of 4, 4, and 5 lower at Sapporo Chuo Ward Kita-2, Sapporo Chuo Ward Minami-4, and Sapporo Nishi Ward Kotoni, respectively (JMA 2019). The questionnaire survey was targeted at residents of the buildings. After obtaining consent from the condominium management company and management association for each building in advance, a questionnaire was placed in the mailbox for each dwelling unit. Each response was collected using an enclosed reply envelope for Buildings A and B, while it was collected by placing it in the mailbox of the management office for Building C. The questionnaire survey was conducted from late November to mid-December 2018 for Buildings A and B, and from mid-April to early May 2019 for Building C. The reason why several months passed from the occurrence of the earthquake to the implementation of the questionnaire survey for Building C was that it took time to obtain permission for the survey from the condominium management company and management association.

The questions on the questionnaire were mainly taken or adapted from the previous studies (Hida and Nagano 2012; Architectural Institute of Japan 2013; Nagano et al. 2018) of questionnaire surveys for high-rise residential buildings subjected to the 2011 Tohoku Earthquake and the 2016 Kumamoto Earthquake. The questionnaire included the following questions:

- On what floor of the condominium is your dwelling unit?
- Where were you when the earthquake occurred?
- What was your situation when the earthquake occurred?
- How much shaking did you feel intuitively? (Please answer based on your intuition.)
- What was the degree of shaking due to the earthquake that you felt?
- How did the shaking feel?

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Table 1. Overview of the buildings surveyed.

| Building name | Building A | Building B | Building C |
|---------------|------------|------------|------------|
| Location      | Sapporo    | Sapporo    | Sapporo    |
| Superstructure type | Reinforced concrete | Reinforced concrete | Reinforced concrete |
| Usage type    | Condominium | Mainly condominium | Condominium |
| Number of aboveground floors* | 26–30 | 38–42 | 38–42 |
| Number of dwelling units* | 90–120 | 320–340 | 200–230 |

*Described with a range to avoid building identification.

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Figure 2. Ground motions observed at HKD180 (K-NET Sapporo) during the 2018 Hokkaido Eastern Iburi Earthquake: (a) time history accelerations; (b) acceleration response spectra; (c) velocity response spectra; and (d) displacement response spectra.
• Did you feel scared during the strong shaking?
• What was the reason that you felt “A little scared,” “Scared,” or “Very scared” in the previous question? (Multiple answers possible.)
• When did you notice the earthquake?
• What action did you take when you noticed the earthquake?
• What action did you take during the strong shaking? (Please select up to two answers.)
• Did you feel any trouble when you took the actions reported in the previous two questions?
• If you answered “I felt a little trouble,” “I felt trouble,” or “I felt very much trouble” in the previous question, what was the reason? (Multiple answers possible.)
• How was the state of your family during the strong shaking?
• What did you do within 30 minutes after the shaking subsided? (Please select up to two.)
• Did anyone in your family who were in the dwelling unit at the time of earthquake suffer an injury? If so, please describe the situation and the degree of injury.
• Did you experience the following symptoms after the shaking of the earthquake?
• Did a chest, bookshelf, cupboard, etc., fall down or move significantly?
• Did a TV, microwave oven, etc., fall to the floor?
• Did furniture with casters, home appliances, pianos, etc., move around?
• Did you see any cracks in the indoor wallpaper of the interior materials?
• Did the walls have cracks or other damage?
• Was there damage such as cracks on the window glass?
• Did the ceiling have any damage, such as displacement, chipping, or dropping of the ceiling plate?
• Was there any damage such as a door being made difficult to open or close?
• Was there any water leaking?
• Did you take any measures to prevent furniture, such as chests, bookshelves, and cupboards, from falling down before the earthquake?
• If you answered “Measures had been taken for most furniture” or “Measures had been taken for some furniture” in the previous question, what measures were taken? (Multiple answers possible.)
• Other than preventing furniture from falling down, did you take any measures before the earthquake? (Multiple answers possible.)
• Were the earthquake measures mentioned in the previous two questions useful in this earthquake?
• Were there any earthquake measures newly adopted in your home after this earthquake? (Multiple answers possible.)
• What do you think about the need for the Earthquake Early Warning (TV, radio, smartphone, etc.)?
• What kind of measures do you think will be necessary at your dwelling unit in preparation for a major earthquake such as this one, or an earthquake larger than this one? (Free-form comment.)
• Please tell us anything else you noticed or felt after experiencing this earthquake. (Free-form comment.)

In addition to the above questions, several questions regarding the blackout were added in the questionnaires for Buildings A and B. Also, a hearing was conducted with the condominium management company regarding the situation of the blackout for each building, if it was permitted.

The questionnaires were posted to almost all the dwelling units for the three buildings, and the total number distributed was 615. All the questions in the questionnaire were originally written in Japanese and the responses were also written and submitted in Japanese; the questions and responses reported in the present paper were translated into English by the authors. To compile and analyze the questionnaire results, the authors followed the previous studies (Hida and Nagano 2012; Nagano et al. 2018) to divide each building into three parts according to height. Accordingly, the obtained responses were allocated to one of the three groups [i.e., the higher (H), middle (M), and lower (L) floors].

3. Results and discussion

The number of valid responses obtained was 28, 95, and 82 for Buildings A, B, and C, respectively, for a total of 205 responses. The response rate for all the three buildings as a whole was 33%.

3.1. Experience of shaking during the earthquake

Figure 3 shows the location at the time of the earthquake reported by each respondent. This was obtained from the question “Where were you when the earthquake occurred?” Most of the respondents answered that they were at home. The situation of the residents at the time of the earthquake, which was obtained from the question “What was your situation when the earthquake occurred?”, is shown in Figure 4. Because the earthquake occurred at 3:07 am, in the middle of the night, around 88%–89% of the respondents for each building answered that they were asleep but woke up due to the shaking of the earthquake.

Figure 5 shows the response results for sensory seismic intensity obtained from the question “How much shaking did you feel intuitively?” The sensory seismic intensity here refers to the seismic intensity
subjectively felt by the occupants who were affected by the shaking of the earthquake (Nagano et al. 2018). (In the figures, H, M, and L on the x-axis refer to the higher, middle, and lower floor groups, respectively, as described in Section 2.) In this question, no explanation about the seismic intensity scale was provided to the respondents. That is, the occupants were asked to answer (from the choices) the sensory seismic intensity that they intuitively felt without any explanatory information of the seismic intensity. In Japan, when an earthquake occurs, a quick report of “Earthquake and Seismic Intensity Information” on TV etc. is informed, thus it is inferred that many of the respondents knew the existence of the seismic intensity scale. Although the reported sensory seismic intensity varied, most of the respondents reported feeling a sensory seismic intensity roughly comparable to the seismic intensity of 4 through 5 upper observed near the three buildings (Section 2). Figure 6 shows the response results regarding their difficulty in taking voluntary action during the earthquake, which was obtained from the question “What was the degree of shaking due to the earthquake that you felt?” The difficulty in action here refers to the degree of difficulty in making voluntary movements during the earthquake shaking (Nagano et al. 2018). Approximately 56%, 36%, and 54% of the respondents for Buildings A, B, and C, respectively, answered that shaking resulted in at least some difficulty in volitional behavior. From Figures 5 and 6, regarding the sensory seismic intensity and the

Figure 3. Result for the question “Where were you when the earthquake occurred?”

Figure 4. Results for the question “What was your situation when the earthquake occurred?”

Figure 5. Results for the question “How much shaking did you feel intuitively? (Please answer based on your intuition.)” Note: H, M, and L refer to higher, middle, and lower floors, respectively.
difficulty in action, no clear tendency was shown among the dwelling floor groups (i.e., higher, middle, and lower floors) for each building. In the past questionnaire survey (Nagano et al. 2018) of high-rise residential buildings for the 2016 Kumamoto Earthquake, it was reported as follows: for buildings in Kumamoto where seismic intensity 6 upper was observed, as the dwelling floor group became higher, the sensory seismic intensity and the difficulty in action became larger and more difficult, respectively; while for buildings in Fukuoka where mainly seismic intensity 4 was observed, the tendency among the dwelling floor groups was not clear. The similar unclear tendency shown in Figures 5 and 6 in the present survey for the 2018 Hokkaido Eastern Iburi Earthquake was likely due to the relatively not strong ground motions (i.e., seismic intensity of around 4 through 5 upper) that were input to the buildings located in Sapporo.

Figure 7 shows the reply results for how the residents felt the shaking obtained from the question “How did the shaking feel?” Figure 8 shows the results for the degree of anxiety during the earthquake from the questions of “Did you feel scared during the strong shaking?” Figure 9 shows the results for why the earthquake was scary from the question “What was the reason that you felt ‘A little scared,’ ‘Scared,’ or ‘Very scared’ in the previous question?” From Figures 7–9, different residents perceived the shaking in various ways, but approximately 81%, 90%, and 92% of the respondents from Buildings A, B, and C, respectively, felt at least a little scared, mainly due to the magnitude of shaking, the length of shaking, and the creaking noise produced by the moving building. Figure 10 shows the reply results regarding the timing when the occupants noticed the earthquake obtained from the question “When did you notice the earthquake?” Roughly 26%, 17%, and 24% of the respondents from Buildings A, B, and C, respectively, noticed the occurrence of the earthquake from audible alarms of the Earthquake Early Warning (EEW) provided by JMA (2007); however, most of the others were aware of the earthquake by feeling the shaking.

Figure 11 shows the reply results for the first action taken when the occupants noticed the earthquake obtained from the questions “What action did you take when you noticed the earthquake?” Also, Figure 12 shows the results for the action taken during the vibration of the earthquake obtained from the question “What action did you take during the strong shaking?” From Figures 11 and 12, although there were variations, the answer “I stood ready to be able to evacuate immediately” was relatively prevalent. Figure 13 shows the reply results regarding the degree of hindrance to take action, as obtained from the question “Did you feel any trouble when you took the actions reported in the previous two questions?” Figure 14 shows the results for the reason of having

Figure 6. Results for the question “What was the degree of shaking due to the earthquake that you felt?”

Figure 7. Results for the question “How did the shaking feel?”
Figure 8. Results for the question “Did you feel scared during the strong shaking?”

Figure 9. Results for the question “What was the reason that you felt ‘A little scared,’ ‘Scared,’ or ‘Very scared’ in the previous question? (Multiple answers possible.)”

Figure 10. Results for the question “When did you notice the earthquake?”

Figure 11. Results for the question “What action did you take when you noticed the earthquake?”
felt hindrance to taking action, as obtained from the question “If you answered ‘I felt a little trouble,’ ‘I felt trouble,’ or ‘I felt very much trouble’ in the previous question, what was the reason?” From Figures 13 and 14, approximately 48%, 52%, and 45% of the respondents from Buildings A, B, and C, respectively, did not feel any hindrance to their behavior; however, the others felt various degrees of hindrance, and the main reason for this was that the shaking was strong and they were upset. Figure 15 shows the results for the state of the respondent’s family during the shaking due to the earthquake from the question “How was the state of your family during the strong shaking?”

Figure 16 shows the response results for the action taken within 30 minutes after the shaking subsided, as obtained from the question “What did you do within 30 minutes after the shaking subsided?” It showed that approximately 57%, 41%, and 71% of the respondents from Buildings A, B, and C, respectively, turned on the TV or radio within 30 minutes after the shaking subsided. It can be inferred that many people in Hokkaido took a similar action (i.e., turning on the TV) after the earthquake for obtaining earthquake information, which boosted the demand for electricity immediately after the earthquake.

All respondents from all three buildings answered “None” to the question “Did anyone in your family who were in the dwelling unit at the time of earthquake suffer an injury? If so, please describe the situation and the degree of injury.” Figure 17 shows the results regarding the changes in the physical condition of the respondents due to the shaking of the earthquake obtained from the question “Did you experience the following symptoms after the shaking of the earthquake?” Approximately 29%, 31%, and 43% of the respondents from Buildings A, B, and C, respectively, felt continued shaking, even after the earthquake subsided; however, except for two respondents, the rest did not feel any particular changes in their physical condition.

The obtained difficulty in action and anxiety that the residents felt during the shaking of the earthquake were relatively small compared with that reported in the previous survey results (Hida and Nagano 2012; Nagano et al. 2018) for the 2011 Tohoku Earthquake (Kanto region) and the 2016 Kumamoto Earthquake (Kumamoto area). This was because the ground motions that were input by the 2018 Hokkaido Eastern Iburi Earthquake into the three surveyed buildings located in Sapporo were not as severe.

3.2. Damage situation due to the shaking

From the results for the question “Did a chest, bookshelf, cupboard, etc., fall down or move significantly?”, all the answers were “No,” except approximately 0%,
Figure 14. Results for the question "If you answered 'I felt a little trouble,' 'I felt trouble,' or 'I felt very much trouble' in the previous question, what was the reason? (Multiple answers possible.)."

Figure 15. Results for the question "How was the state of your family during the strong shaking?"

Figure 16. Results for the question "What did you do within 30 minutes after the shaking subsided? (Please select up to two.)."

Figure 17. Results for the question "Did you experience the following symptoms after the shaking of the earthquake?"
### Table 2. Summary of the power outage for Building A.

| Duration of power outage | Approximately 38 hours. |
|--------------------------|-------------------------|
| Emergency power supply   | An emergency power supply was deployed, and it operated for around 2 days. |
| Elevator                 | During the power outage, one elevator was available for a limited time. |
| Lifelines (electricity, heat, and water) | In the dwelling units, electricity and water were unusable until power was restored. However, water was available in the common area on the first floor. |
| Parking lot              | Parking was unusable due to the power outage. |
| Emergency stairs         | It was difficult to use the stairs inside the building because the lighting was off due to the power outage. |

### Table 3. Summary of the power outage for Building B.

| Duration of power outage | Approximately 38 hours. |
|--------------------------|-------------------------|
| Emergency power supply   | A generator was deployed, and it operated for around 7–8 hours. |
| Elevator                 | Elevators were unusable until an inspection was completed after power was restored. |
| Lifelines (electricity, heat, and water) | The dwelling units are all-electric. Electricity and water in the dwelling units were unusable after the generator stopped until power was restored. |
| Parking lot              | Mechanical parking was unusable until an inspection was completed after power was restored. |
| Emergency stairs         | After the generator stopped, the lighting was off and it was difficult to use the stairs inside the building. |

### Table 4. Summary of the power outage for Building C.

| Duration of power outage | Approximately 40 hours. |
|--------------------------|-------------------------|
| Emergency power supply   | A generator was deployed, and it operated for around 27 hours until running out of fuel. An inspection was completed around 3 hours after the earthquake occurrence, after which elevators were available during operation of the generator. Initially, three elevators were operational, but after a while, only one elevator was operated to save generator fuel. After the generator stopped, no elevators were available. |
| Elevator                 | The dwelling units are all-electric. The dwelling units, electricity was unusable until power was restored; however, water was available during operation of the generator. Toilets in common areas on the first and second floors were available during generator operation. |
| Lifelines (electricity, heat, and water) | The entrance gate of the building parking lot could not function due to the power outage. |
| Parking lot              | It was difficult to use the stairs inside the building because the lighting was off due to the power outage. |

1%, and 2% of the respondents from Buildings A, B, and C, respectively, who answered “Yes.” Similarly, from the results for the question “Did a TV, microwave oven, etc., fall to the floor?”, all the answers were “No,” except approximately 0%, 0%, and 1% of the respondents from Buildings A, B, and C, respectively, who answered “Yes.” Also, from the results for the question “Did furniture with casters, home appliances, pianos, etc., move around?”, all the answers were “No,” except approximately 12%, 0%, and 3% of the respondents from Buildings A, B, and C, respectively, who answered “Yes.”

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**Table 5. Free-form comments from the occupants of Building A (excerpts).**

The power outage was long and hard. I experienced for the first time that water could not be used in my condominium during the power outage. When I looked into the evacuation place, it was an environment very hard for me to enter and stay. Although water did not come out of the faucet, there was little damage, such as things falling, and I thought it would be safe to stay at home. At least 5 days of water, food, and toilets should be secured. It is necessary to prepare for a major earthquake in winter. The alarm of the Earthquake Early Warning sounded very unpleasant and horrifying. It was very helpful that water was available even only on the first floor. I thought that the residents felt at ease because the condominium management association functioned. Because the airtightness of the condominium is high, there is danger of carbon monoxide poisoning when using fossil fuels. Thus, I am anxious how much I can overcome the cold with winter clothes and a sleeping bag when a disaster occurs in winter.

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**Table 6. Free-form comments from the occupants of Building B (excerpts).**

Preparation of 2–3 days of food and water is needed. It could have been worse if the earthquake and blackout occur in a cold winter period. Because I am old, use of the stairs was physically unreasonable, so I was worried that I could not get out of the dwelling unit. Living in the higher floors has a risk that long-term stay at home is difficult without elevators. There is a possibility of a car accidentally falling when the mechanical parking stops working due to a power outage, and countermeasures should be examined. It is necessary to stockpile food on a daily basis. I live on a higher floor and use of the stairs is physically hard for me, so I cannot go out when the elevators are unavailable. The condominium management appropriately gave announcements in the building to tell the residents how much time the emergency power supply would be available for and what would happen after the power supply ended. Therefore, the residents could effectively use the 7 hours when the emergency power supply was available. The emergency stairs inside the building were pitch black and it was very scary to descend the stairs from the higher floors. It took a very long time because I had to take each step slowly. I was anxious because I could not use the TV or radio, and thus no information was received.

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**Table 7. Free-form comments from the occupants of Building C (excerpts).**

We need something to get information, such as a radio. A smartphone battery should be prepared. I thought that a stockpile of food and water, a battery for charging a smartphone, and a radio were absolutely necessary. The contact information of relatives and close acquaintances should be made clear. To prevent stumbling accidents and secure an escape route, reducing the number of possessions and creating more space through tidiness should be done. It is necessary to consider securing living and evacuation sites for people who live in the higher floors. (For example, is it possible for people living in the lower floors to help or house them if elevators are not available?) The high-rise residential building is inconvenient if elevators are not available. Even if we want to evacuate, we cannot do it if we have children or old people. I was very scared because the high-rise condominium shook greatly. This building is all-electric and we are not permitted to bring in kerosene for stoves, so how can I stay warm if such a blackout occurs in winter?
From the results for the question "Did you see any cracks in the indoor wallpaper of the interior materials?", approximately 4%, 15%, and 10% of the respondents from Buildings A, B, and C, respectively, replied that there were some cracks in the indoor wallpaper; however, the others replied that there were no cracks. Based on this, it is considered that the interior materials were not seriously damaged by the shaking of the earthquake. From the results for the question "Did the walls have cracks or other damage?", all the answers were "No," except approximately 4%, 4%, and 4% of the respondents from Buildings A, B, and C, respectively, who answered "Yes." From the results for the question "Was there damage such as cracks on the window glass?", all the answers were "None" for each of the three buildings. From the results of inquiring "Did the ceiling have any damage, such as displacement, chipping, or dropping of the ceiling plate?", all the answers obtained were "No" for all the buildings. From the results for the question "Was there any damage such as a door being made difficult to open or close?", approximately 0%, 1%, and 2% of respondents from Buildings A, B, and C, respectively, replied "Yes," and all the others answered "None." From the results of inquiring "Was there any water leaking?", all the answers were "None," except approximately 1% of respondents from Building B, who answered "Yes."

From the above, the damage to and overturning of furniture and the damage to the interior and structure by the shaking of the earthquake were not significant for any of the three buildings. This is consistent with the fact that the seismic intensities of 4 through 5 upper were observed at the observation points near the three buildings (Section 2), which are not very severe input ground motions.

3.3. Impact of the long-term blackout

The situation during the power outage estimated from the survey results for each building is described as follows and summarized in Tables 2–4. Overall, it took approximately 38–40 hours to restore the power to each building after the initial power loss.

In Building A, an emergency power supply was in operation for around 2 days, but it was able to provide minimum electricity to only common areas. This enabled the use of one of two elevators for a limited time. Therefore, it was possible to go in and out of the building and to travel easily between floors even during the blackout. In contrast, private areas had no power, and thus residents were unable to use electricity and water in their dwellings.

Regarding Building B, an emergency power generator started operating immediately after the power outage, and it was able to provide electricity to private areas. Around 7–8 hours later, the generator stopped due to a lack of fuel. However, building management staff anticipated this fuel exhaustion in advance. While the emergency power supply was still operating during the blackout, a total of three announcements were made by management staff to inform the occupants about the remaining operating time of the emergency power supply and to call for water storage. Due to the shaking of the earthquake, all elevators automatically stopped for safety, and the elevators could not be restarted until an inspection by a contractor was completed after the power outage was resolved. As a result, especially elderly people living in the higher floors had difficulty leaving their units.

The power outage occurred for Building C around 10–20 minutes after the earthquake struck. Once the power outage occurred, an emergency power generator was started immediately. During the operation time of the generator, a contractor inspection was completed around 3 hours after the earthquake, and three elevators were initially made available for use; however, during the middle of the outage (i.e., around noon on the day of the earthquake), two elevators were taken out of service, and thereafter only one elevator was available. Around 27 hours after the earthquake (i.e., in the morning of the second day), the emergency generator stopped due to lack of fuel, and the remaining elevator became unavailable. After around 11.5 hours afterward (i.e., during the evening on the second day), fuel was procured and the generator was restarted, again providing emergency power. Three building broadcasts were carried out to provide information on water savings and the available facilities inside the hall. Also, a public relations paper for the residents was issued to ensure accurate information transmission. It took around 40 hours to recover from the power outage.

The above sequences of events showed that each building had an emergency power supply, and that it functioned as intended during the power outage. However, the adopted operation methods for the emergency power supply were different among the three buildings, resulting in differences in the availability of facilities, such as elevators, in common areas. Although the size and number of dwelling units and the total electricity demand in each building are different, it can be said that the adopted operation method of the emergency power supply affected the mobility and convenience of the residents during the long-term blackout.

3.4. Earthquake countermeasures before and after the earthquake

Figure 18 shows the response results regarding the situation of securing furniture as an earthquake measure before the earthquake occurred, as obtained from the question "Did you take any measures to prevent furniture, such as chests, bookshelves, and cupboards,
from falling down before the earthquake?” Approximately 61%, 58%, and 50% of respondents from Buildings A, B, and C, respectively, answered that they took no measures to secure furniture, and the others answered that they took various measures. Figure 19 shows the results for measures taken to prevent furniture and other items from overturning, as obtained from the question “If you answered ‘Measures had been taken for most furniture’ or ‘Measures had been taken for some furniture’ in the previous question, what measures were taken?” Overall, a relatively large number of the respondents took the measure “Tension rods were placed between the ceiling and furniture” and/or “A mat was laid under furniture to tilt it.” Figure 20 shows the results for measures adopted since before the earthquake occurred to prevent furniture from overturning, as obtained from the question “Other than preventing furniture from falling down, did you take any measures before the earthquake?” As a whole, the measures of “Flashlight or lantern was prepared,” “Emergency food and water were prepared,” and “Placement of heavy objects on high places was avoided” were the most frequently methods adopted before the earthquake. Figure 21 shows the results for usefulness against this earthquake of the adopted measures obtained from the question “Were the earthquake measures mentioned in the previous two questions useful in this earthquake?” Overall, roughly 95%, 88%, and 91% of the respondents from Buildings A, B, and C, respectively, answered that the earthquake countermeasures that they adopted were useful or very useful in the earthquake.

Figure 22 shows the reply results regarding measures that were newly adopted after the earthquake occurred, as obtained from the question “Were there any earthquake measures newly adopted in your home after this earthquake?” By comparing Figure 19, 20, and 22, a trend can be seen in the earthquake countermeasures before and after the occurrence of the 2018 Hokkaido Eastern Iburi Earthquake. It was found that roughly 89%, 78%, and 89% of the respondents from Buildings A, B, and C, respectively, took some new measures after the earthquake, although it caused almost no indoor damage (Section 3.2). Many residents experienced the shaking of the earthquake and inconvenience and anxiety due to the blackout for a long time after the earthquake. Such an experience would have been the first time for most of the residents, and it would have led to actions for adopting new measures against future earthquakes. Particularly, from Figure 22, the items for earthquake countermeasures that increased after the earthquake were “Flashlight or lantern was prepared” and “Emergency food and water were prepared.” Although these two practices were already relatively common before the earthquake (Figure 20), it is considered that their adoption has been further increased because of the actual experience that building lifelines, such as electricity and water, were interrupted by the long-term power outage.

Figure 23 shows the reply results regarding the necessity of the EEW obtained from the question “What do you think about the need for the Earthquake Early Warning (TV, radio, smartphone, etc.)?” Approximately 71%, 77%, and 84% of the respondents from Buildings A, B, and C, respectively, answered that information from the EEW is “Necessary” or “Absolutely necessary.” However, a few respondents gave answers of “Unnecessary” or “Not needed very much.” Their reasons for these answers included “The time from the receipt of the information of the EEW to the beginning of the shaking is short” and “The EEW alarm sound made me feel anxiety.”

### 3.5. Free-form comments

In the questionnaire survey, open-ended questions were provided to allow residents to further express their thoughts, such as the shaking of the building during the earthquake, the situation of and damage to their room, what kind of information was effective before and after the earthquake, effective earthquake countermeasures, other things they noticed, and their anxiety. Tables 5–7 give excerpts from the 38, 55, and 87 comments obtained from Buildings A, B, and C, respectively, which were originally written in

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**Figure 18.** Results for the question “Did you take any measures to prevent furniture, such as chests, bookshelves, and cupboards, from falling down before the earthquake?”.
Japanese and translated here into English, as mentioned in Section 2.

From the results of the obtained free-form comments, there were more comments about the inconvenience and anxiety due to the long-term black-out that occurred after the earthquake than about the shaking due to the earthquake. In particular, noteworthy comments regarding the problems due to the power
outage included the elevators could not be used; the lighting of the stairs inside of the building was not working, making it difficult and dangerous to use the stairs; and the parking lot was inoperable, making it impossible to use personal vehicles. Some elderly residents living on the higher floors reported that they were forced to stay home because it was difficult to move from their home to the ground floor and vice versa. Moreover, comments on the necessity of stockpiling food and water and the usefulness of information transmission by broadcasting in the buildings were also noticeable. Although the earthquake occurred in late summer (September), there were also comments on concerns about the possibility of a long-term blackout during the harsh winter period.

The survey showed that the long-term power outage caused by the earthquake had a major impact on the residents who live in high-rise condominium buildings. Particularly, unavailability of the elevators caused a great inconvenience to the occupants living on the higher floors, and it made outings difficult. Moreover, due to the power outage, the emergency stairs inside the buildings were not illuminated, making them difficult to use.

4. Conclusions

In the present study, a questionnaire survey on the 2018 Hokkaido Eastern Iburi Earthquake was conducted for the occupants of three RC high-rise residential buildings located in Sapporo. The number of valid responses and
the response rate were 205 and 33% in total, respectively. From the results of the survey, the following may be concluded:

(1) For this earthquake, the anxiety and action difficulty due to the shaking felt by the residents were relatively small compared with those obtained from previous surveys for the 2011 Tohoku Earthquake and the 2016 Kumamoto Earthquake. This was because the ground motions input into Sapporo buildings were not very strong, as can be seen in the seismic intensities of 4 through 5 upper observed near the buildings.

(2) The damage to and overturning of furniture and damage to the interior and structure of the buildings by the earthquake shaking were small for all three buildings. This was consistent with the relatively minor ground motions observed in the area where the three buildings are located.

(3) Although all three buildings are equipped with emergency power supplies, each building adopted a different operation method. These different operation methods affected the convenience and mobility of the occupants during the long-term blackout.

(4) It was shown that the long-term blackout due to the earthquake had a great impact on the occupants living in high-rise residential buildings. In particular, when elevators were unusable, this caused great inconvenience to the residents living on the higher floors and made it difficult for them to go out. In addition, due to the power outage, the emergency stairs inside the buildings were not illuminated, making it difficult and dangerous to use the stairs.

(5) The inconvenience and anxiety caused by the complex disaster (i.e., the shaking due to the earthquake followed by the long-term blackout) left a strong impression on the residents. It is inferred that this experience gave them motivation to implement further measures, such as stockpiling of flashlights, lanterns, food, and water, after this complex disaster to prepare against future disasters.

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