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The role of ICT in collective resilience in a time of crisis

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The role of ICT in collective resilience in a time of crisis

[Draft paper]

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Abstract

Studies find that in time of crisis such as natural disasters, in most cases, people in crowds are capable to remain calm and to help each other. Referred as 'collective resilience', this capability can increase a society's capacity to withstand crises and disasters. Therefore, for both academia and governments, it is important to understand the factors and mechanisms of collective resilience. Considering the increasingly important role of ICT in disasters, we anticipate that it can also contribute to collective resilience. However, currently few studies have explored the connections between these two concepts empirically. Thus, the aim of this study is to investigate the roles and effects of ICT in collective resilience in a time of crisis.

This study uses the 2011 Great East Japan Earthquake as the case study. In particular, the large crowds of stranded commuters in Tokyo when the earthquake struck. Using a quantitative approach with 258 samples collected from a survey, the preliminary results have shown the presence of collective resilience among the stranded commuters. For instance, most of them felt a sense of shared identity and interdependence with others. Moreover, the results have also revealed the two main roles of ICT in collective resilience. First, by providing information and advice on what to do, ICT information can keep people in a crowd to stay in the state of collective resilience together. The second role is to reduce the chance of mass panic or herd behaviour. This is because ICT information can increase a person's knowledge of the situation. Such knowledge can help them to make their own decisions rationally, thus reduce their dependence on others.

1. Introduction

In time of crisis such as natural disasters or disease outbreaks, many governments have the perception that the general public is prone to mass panic (Clarke, 2002; Heide, 2004). That being said, researchers, for example, Nogami & Yoshida (2014), Mawson (2012) and Drury, et al. (2009), argue that such perception is only one side of the picture. On the contrary, they have found that in many cases of emergency and disaster, people were capable to self-organise and to help each other to overcome the dire situation. Referred by Drury (2012) as 'collective resilience', these characteristics can greatly increase a society's capacity to withstand crises and disasters (Kosłowski & Longstaff, 2015). Thus, for both academia and governments, it is important to identify and understand the factors and mechanisms of collective resilience.

ICT is becoming increasingly important to help people to stay informed and connected in emergencies and disasters. Therefore, we anticipate that it can also contribute to the development to collective resilience. However, currently few studies have investigated the connections between these two concepts empirically. Thus, the purpose of this study is to investigate the roles and effects of ICT in collective resilience in a time of crisis.

This study uses the 2011 Great East Japan Earthquake – one of the strongest earthquakes in history – as the case study. Specifically, it focuses on the large crowds of stranded commuters amassed near the major train stations in Tokyo when the earthquake struck. This particular case is selected because of two main reasons. First, despite the fact that the crowd density had reached an alarmingly high level (Abe, 2014; Hiroi, 2013), the stranded commuters had remained calm and behaved orderly. Second, when the traditional telephony network was paralysed after the disaster, ICTs such as mobile Internet and social media provided the critical communications platform for many people in Japan (Slater, et al., 2012). Thus, this case study provides the potential evidence of the presence of collective resilience and the influences from ICT in a crisis situation.

1.1 Background – 11 March 2011, Tokyo

At 2:46pm JST, 11 March 2011, the north-east coast of Japan was hit by one of the strongest earthquakes in history - the Great East Japan Earthquake. The disaster has devastated the north-east costal area. According to the Japanese government, it has directly claimed more than 15,800 lives and cost more than 177.7 billion US dollars of damage (Reconstruction Agency, 2013).

Although Tokyo – the capital city – was 373 km away from the epic centre, it was also hit by strong seismic waves. The waves' intensity was measured up to 5-Upper in the Japan Meteorological Agency seismic intensity scale, the strongest since the 1923 Great Kanto Earthquake¹. Compared with the north-east area, in Tokyo the direct physical damaged caused by the earthquake was minor. However, being a mega metropolitan city with more than 13 million inhabitants, the social impacts were substantial (Ueno, 2013).

¹ Japan Meteorological Agency - <http://www.data.jma.go.jp/svd/eqdb/data/shindo/index.php>

One of the most significant and immediate impacts was the disruption of the public transportation networks that most of Tokyo's inhabitants rely on. Soon after the seismic waves hit the city, all train and subway services were stopped. They were suspended for the rest of the day as aftershocks continued to hit the city. By midnight, only 40% of the services had resumed. Since it was a Friday afternoon – a typical business day – it is estimated that 5.15 million commuters were affected. This number exceeds what the city government had previously anticipated by 30% (Hiroi, et al., 2011; Tokyo Metropolitan Government, 2011). The government had advised people to remain where they were and to refrain from rushing home². Yet, large crowds were quickly amassed around the major train and subway stations (Suzuki, 2013).

A study lead by NHK and The University of Tokyo (Abe, 2014) uses mobile phones' GPS and Twitter data to estimate the number of stranded commuters. They estimate that there were at least 320,000 commuters stranded near the major transportation hubs in Tokyo on that day. For example, near Shibuya station – one of busiest transportation hubs in Tokyo – alone (Figure 1), they estimate that there were more than 50,000 stranded commuters between 4pm to 11pm. By At around 7pm, the number had reached 66,000 – 2.5 times more than the number of people during the busiest hour. This represents a crowd density of 6 to 7 persons per square meter – an alarmingly high level according to studies on crowd disasters (Fruin, 1993; Helbing & Mukerji, 2012). Similar situation was also found in other major transportation hubs such as Shinjuku and Tokyo stations.



Figure 1 – Stranded commuters in Shibuya station, 6pm, 11 March 2011. Source: Asahi Shimbun 11 Mar 2011, <http://www.asahi.com/special/10005/TKY201103110519.html>

On top of the intense crowd density, Abe (2014) also shows that the stranded commuters also were under other physical and psychological stresses. For example, physical stress such as coldness and tiredness, and psychological stress such as fear and anxiety. Nevertheless, despite under such a stressful situation, most of the commuters had remained calm and behaved orderly. The crowds slowly dispersed as the train services resumed gradually and some people decided to go home by foot or to return to their original location. It is estimated that 20% of the affected commuters could not return to their home that night (Hiroi, et al., 2011).

² http://www.kantei.go.jp/jp/tyoukanpress/201103/11_p2.html

Overall, no serious injuries or accidents caused by the stranded crowds were reported. That being said, the unexpectedly large number of stranded commuters had raised major concerns in the government. After the disaster, they had issued guidelines specifically on the risk and prevention of stranded commuters in the wake of an earthquake (Tokyo Metropolitan Government, 2012).

On top of the size of the crowds, another very remarkable aspect of this event is the role ICT had played. Soon after the disaster, the telephony network was totally congested, in particular the mobile phone network that most Japanese people rely on³. Most of the people stranded outdoor had difficulty to make communications using their mobile phones for both voice and short messages (Hiroi, et al., 2011). That being said, because mobile data connection was still available, Internet and social media became the main channel for some people to seek and share information. Abe (2014) finds that just on the topic about the situation in Shibuya station alone, more than 35 million tweets were sent over Twitter within 24 hours after the earthquake.

These messages provided the commenters with critical information such as the status of the train services, availability of alternative routes, and latest information about the disaster. This information helped them make decisions, for instance to continue to wait, to return home by foot, or to take an alternative route (Takada, et al., 2012; Hara, 2013). That being said, it should be note that television – including large outdoor television screen and mobile television⁴ – was still regarded as the main source of information by most of the stranded commuters (Hiroi, et al., 2011; Suzuki, 2013).

2 Literature review

2.1 Collective resilience

Social elites and leaders tend to presume that the general public is prone to mass panic and herd behaviour in disaster situations. This is often because of political and institutional reasons (Clarke & Chess, 2008). That being said, studies, for example, Nogami & Yoshida (2014), Mawson (2012) and Drury et al. (2009) have found the contrary. They find that in most cases of emergency and disaster, instead of panicking and hysteria, people in crowds had shown solidarity and cohesion.

Referred as 'collective resilience', Drury (2012) suggests that *'crowds can provide the mutual support, co-ordinated activity and other features of resilience that enable people to cope psychologically with mass emergencies and disasters'* (p. 195). One of the commonly agreed antecedents of collective resilience is pre-existing social bonds (Mawson, 2005). That said, Drury (2012) argues just social bonds alone is insufficient to explain collective resilience. It is because in many cases the crowds were made up of strangers.

³ In 2011, the mobile phone penetration rate in Japan was 94%, and one third of them were smartphones (MIC, 2012).

⁴ Most of the mobile phones in Japan support the 'One-Seg' standard mobile terrestrial digital television broadcasting service.

From a social psychology perspective, he suggests that the core component of collective resilience is 'shared identity'. He explains that when people face a common threat, they will shift from seeing themselves as unique individuals to seeing themselves as fellow members of a group. This shift of perception creates a strong sense of togetherness and subsequently a group-based self-identification or shared identity. Having a shared identity encourage them to work together towards a mutual goal, and affects their behaviours collectively. For example, people in disaster situations will become more interdependent with each other, more willing to help others and to maintain civility. At the same time, they will also have a higher expectation of help and civility from others. This type of interdependence increases their level of coordination, reduce stress and fear, and subsequently help them to overcome the difficult situation. His later works have indeed found these characteristics among the survivors from different disasters (Drury, et al., 2009a; Drury, et al., 2015).

That said, although rare, sometimes crowds of people can also lead to disasters such as stampedes. Zhen et al. (2008) point out that the risk of crowd disasters is increasing because large crowds are becoming more common in modern societies. For example, crowds formed by man-made causes such as sports or religious events, as well as unexpected causes such as natural disasters.

From a physics perspective, studies, for example, Fruin (1993), Helbing & Mukerji (2012) and Murosaki (2002), find that one of the main causes of crowd disasters is 'crowd density'. When the crowd's density reaches 6 to 7 persons per square meter, the crowd will become fluid mass. At this point, even a small push from a single person will propagate through the mass to create a huge force. Such force can create a domino effect, thus trigger a stampede.

On top of crowd density, studies find that psychological factors such as panic can also trigger a crowd disaster (Zhen, et al., 2008; Helbing & Mukerji, 2012; Murosaki, 2002). As Ma & Larrañaga (2011) note, although panic might not the root cause of crowd disasters, it is often the catalyst, which makes bad situation worse. Similarly, Zhen, et al. (2008) point out that panic is often the turning point between a controllable and uncontrollable crowd in crowd disasters.

2.2 Critical transitions

The concept of critical transitions (Scheffer, 2009; Scheffer, et al., 2012) explains how a seemingly stable system – for example, a controllable crowd - can suddenly shift to a contrasting state – for example, an uncontrollable crowd – collectively. This sudden shift occurs when the external stress exceeds the system's threshold – the 'tipping point'.

The core mechanism of the tipping point is the feedback between individuals in the system. For example, if the individuals in the systems are loosely connected and heterogeneous, they will react independently to external stress. From a system perspective, they will cancel out each other's reaction. Therefore, the overall system will respond gradually to the external stress, as shown on the left hand side of Figure 2. In other words, a loosely connected system is less resistant to change under external stress. However, its rate of change is more gradual and predictable.

On the other hand, in a complex system that individuals are highly interconnected and homogeneous, their responses to external stress will be affected by one another. Thus, from a system perspective, their reactions will be locked into a positive feedback loop. When the level of external stress increases, they will remain in one state collectively until the level of stress exceeds the system's tipping point. At this point, even a small force can propel the system to rapidly shift to an alternative state as shown on the right hand side of Figure 2. Thus, a highly connected and homogeneous system is more resistant to change under external stress. However, when the change occurs, it tends to be sudden and rapid.

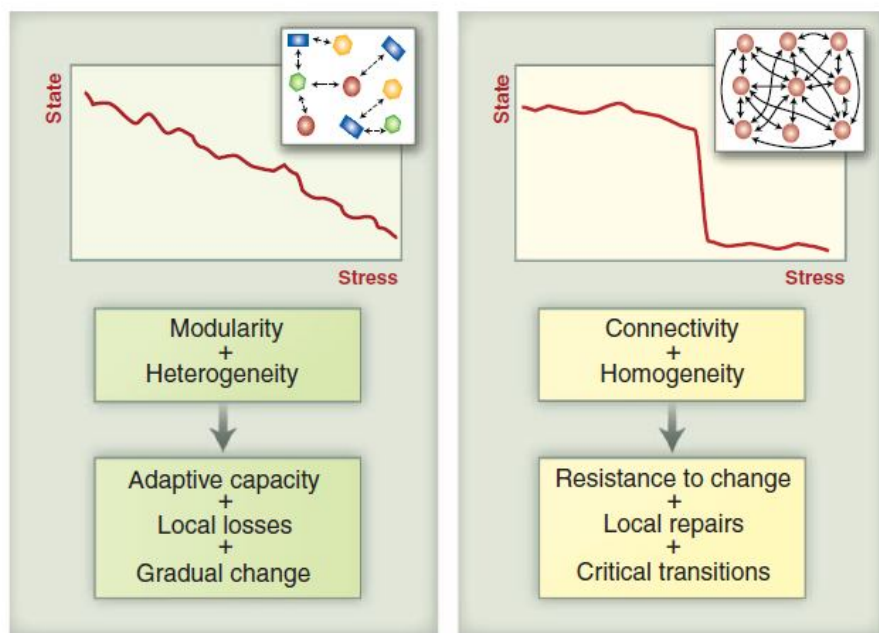


Figure 2 – Critical transitions. Source (Scheffer, et al., 2012, p. 338)

This concept is originated in ecology to explain the abrupt changes observed in ecosystems. It has been adopted to explain the tipping points in social and economic systems. In the case of human society, Scheffer (2009) suggests that there are two more factors that can affect the occurrence of critical transitions in a society when it is under external stress.

The first factor is the presence of leaders. This is because in the wake of an unexpected external shock, people tend to follow the advice from leaders. Thus, leading figures can increase the homogeneity of the group. For example, a leader can persuade individuals to follow the same advice or instructions, and to remain in the same state to withstand the external stress. In parallel, a leader can also persuade individuals to act together to counter the external stress, thus to trigger the tipping point.

The second factor is the complexity of issues causing the external stress. This is because people tend to follow others if they do not have sufficient knowledge or understanding of the issue to make their own choice rationally. In other words, the less information people have, the higher the level of their interdependence, thus the higher chance of herd behaviour.

3. Assumptions and hypotheses

Based on the literature review, we can now make the following assumptions.

First, on 11 March 2011, the crowds of stranded commuters amassed near the major transportation hubs in Tokyo had created a potential crisis situation. In particular, the intense crowd density plus the fear and stress caused by the earthquake could trigger a crowd disaster. That said, in line with the literature on collectively resilience, most of the stranded commuters had remained calm and orderly. We therefore hypothesise the stranded commuters had shown collective resilience, which includes factors such as shared identity, interdependence and mutual help. Thus,

- Hypothesis H1 – there was a sense of collective resilience among the commuters when they were stranded near the main train and subway stations on 11 March 2011.

Secondly, according to the literature on critical transitions, a group's homogeneity and interconnectivity can keep individuals in the group to stay together in a same state. Connecting this concept with collective resilience, we contend that these two factors are similar to shared identity – homogeneity – and interdependence – interconnectivity – respectively. Thus, in this case, we assume that collective resilience has contributed to keep the stranded commuters together in a calm and orderly state.

According to Scheffer (2009), a group's homogeneity and interconnectivity can be affected by two factors - the complexity of issue and the presence of leaders. This is because leaders can keep individuals to act in a similar way, thus increase their homogeneity. At the same time, the more complex the issue is, the more likely people will follow others, thus increase their interdependence. Therefore, we assume that by providing information of the disaster and advice on what to do, ICT information can contribute to collective resilience. This is because ICT information can provide advice to the stranded commuters on what should they do, it can act as the role of a leader. Thus, for the stranded commuters, we anticipate that

- Hypothesis H2 – Information and advice on what to do increase the level of collective resilience.

At the same time, ICT information can also reduce the level of complexity because it can provide knowledge of the disaster to the stranded commenters. Thus, reduce their level of interdependence. Therefore, for the stranded commuters, we hypothesise that

- Hypothesis H3 – Knowledge of the disaster reduces the level of collective resilience.

Thirdly, we assume that knowledge and advice can be obtained from different ICTs⁵ such as television⁶, radio and mobile phones. Thus, for the stranded commuters, we hypothesise that

- H4-1 – Information from mobile phone (voice and messages) increases the amount of advice they received.

⁵ Television, followed by mobile phones and radio were the most useful information source for the stranded commenters according to (Hiroi, et al., 2011).

⁶ Including portable television (One-Seg), large outdoor television and television in public areas.

- H4-2 – Information from mobile phone (Internet) increases the amount of advice they received.
- H4-3 – Information from television increases the amount of advice they received.
- H4-4 – Information from radio increases the amount of advice they received.
- H5-1 – Information from mobile phone (voice and messages) increases their knowledge of the disaster.
- H5-2 – Information from mobile phone (Internet) increases their knowledge of the disaster.
- H5-3 – Information from television increases their knowledge of the disaster.
- H5-4 – Information from radio increases their knowledge of the disaster.

Finally, we also anticipate that staff at the train and subway stations can also provide information and advice. Thus, it is added as a control variable together with age and gender. The above hypotheses are represented by a path diagram shown in Figure 3.

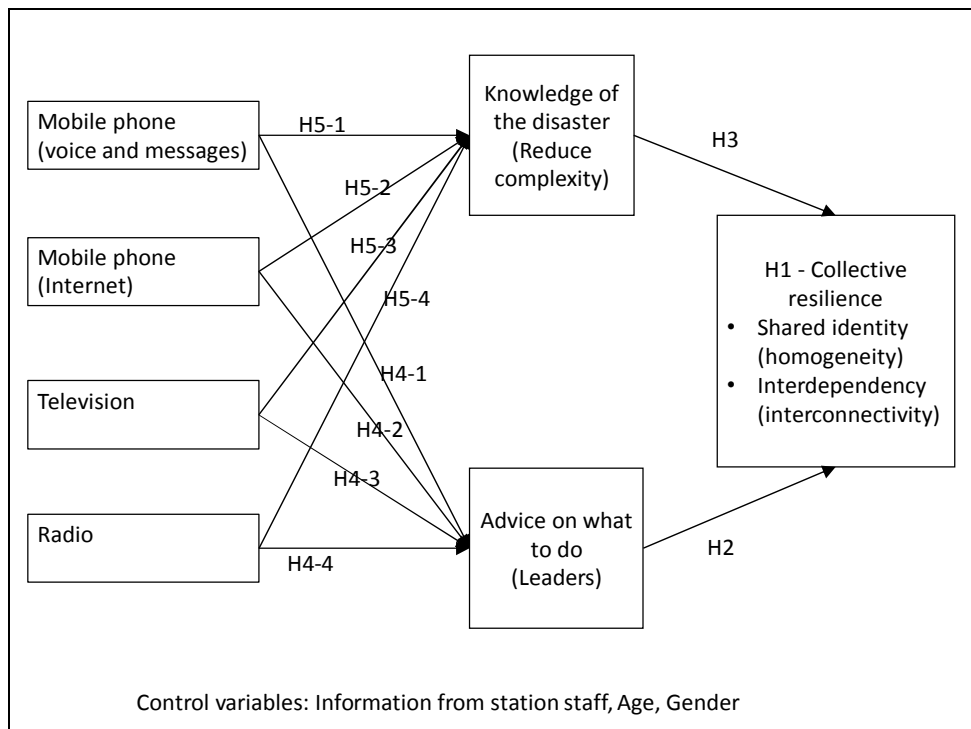


Figure 3 - Path diagram

4. Methodology

The hypotheses were examined using a quantitative approach with a data set collected from an Internet questionnaire survey⁷. The variable 'collective resilience', 'knowledge' and 'advice' in the path diagram (Figure 3) were represented as latent variable⁸.

⁷ Originally in Japanese, translated by the author.

⁸ Variables that cannot be measured directly such as social or psychological status but can be represented by a set of observed variables which can be measured directly (Tabachnick & Fidell, 2013).

Data for these variables were operationalised by asking the respondents *'On 11 March 2011, when you were stranded near the train or subway stations and had difficulties returning home. Do you agree with the followings based on your own experience?'* in a 5 level Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

First of all, 'collective resilience' was represented by the following four factors selected based on previous studies (Drury, et al., 2009a; Drury, et al., 2015).

- 1.1 Shared identity – *'I felt a sense of unity with the other people around me.'*
- 1.2 Helped others – *'I had helped other people.'*
- 1.3 Helped by others – *'I was helped by other people.'*
- 1.4 Interdependence – *'My decisions and actions were affected by other people.'*

Secondly, 'advice' was measured by the level of information and advice to the stranded commuters received from different ICT sources.

- 2.1 Mass media – *'I received clear information and advice on what to do from mass media.'*
- 2.2 Internet media – *'I received clear information and advice on what to do from the Internet or social media.'*

Thirdly, 'knowledge' was represented by the stranded commuters' level of knowledge of the followings three items. These three items are selected because according to Hiroi et al. (2011), they are the stranded commuters' most wanted to know information.

- 3.1 Earthquake – *'I knew about the location and the scale of the earthquake.'*
- 3.2 Family safety – *'I knew about the safety status of my family.'*
- 3.3 Transportation status – *'I knew about the public transportations' service status (for example, bus, train and subway).'*

Fourthly, the different ICTs were represented by the following four questions.

- 4.1 Mobile phone (voice, messages) – *'I received useful information from mobile phone (voice, messages).'*
- 4.2 Mobile phone (Internet) – *'I received useful information from mobile phone (Internet).'*
- 4.3 Television – *'I received useful information from television (including portable television, outdoor television screen, television in shops and station etc.).'*
- 4.4 Radio – *'I received useful information from radio (including portable radio, car radio, radio in shops and in other public facilities etc.).'*

Finally, the respondents were asked the following questions to evaluate their level of stress and the surrounding environment.

- 5.1 Crowded environment – *'I felt stressed from the crowded environment.'*
- 5.2 Physical stress – *'I felt stressed from coldness, hunger or tiredness because of long hours of waiting.'*
- 5.3 Mental stress – *'I felt fear and anxious because of the earthquake and aftershocks.'*
- 5.4 Other people's behaviours – *'I felt people around me acted calmly and orderly.'*
- 5.5 Staff – *'I received clear information and advice on what to do from the station staff.'*

5. Data and result analysis (preliminary)

5.1 Data set

The data set was collected from an Internet survey⁹ conducted in August 2015 sponsored by the Japan Commercial Broadcaster Association. In total, 2,073 samples were collected from the Greater Tokyo region¹⁰.

Among them, 1,978 were living in the Great Tokyo region when the earthquake struck and reported that they could remember what happened. Within this group, 384 of them reported that they were stranded near a train or subway station and had difficulty returning home on 11 March 2011. Among them, 258 reported they felt stressed from staying in a crowded environment near the station. Thus, they were selected for this analysis. The average age of this group was 41.8 years old, the standard deviation was 14.7. The youngest was 16 years old and the oldest was 76 years old. 49.6% of them were male and 50.4% were female.

The mean, standard deviation, range, code of their response to the questions are summarised in Table 1. First, the means of both physical and mental stress – 5.2 and 5.3 – were above mid-point level of 3, and their standard deviations are quite low relatively. These imply that most of them did feel a higher than usual level of physical and mental stress. That being said, the mean of 5.4 shows that they also felt most people behaved calmly and orderly. Second, the means of different ICTs – 4.1, 4.2, 4.3 and 4.4 – show that television and mobile phone (voice and messages) were the most useful information source for the stranded commuters. Final, the Cronbach's alpha¹¹ of the three latent variables are at an acceptable level, which means that they can be represented by the observed variables reliably.

Table 1 Latent and observed variables

| | Latent variable | Observed variable | Code | Mean | SD | Range | Cronbach's alpha |
|---|-----------------------|-------------------|--------------------------------|------|------|-------|------------------|
| 1 | Collective resilience | 1.1 | C1 - Shared identity | 3.25 | 1.22 | 1 - 5 | 0.753 |
| | | 1.2 | C2 - Helped others | 2.76 | 1.25 | | |
| | | 1.3 | C3 - Helped by others | 2.54 | 1.21 | | |
| | | 1.4 | C4 - Interdependence | 3.19 | 1.16 | | |
| 2 | Advice | 2.1 | A1 - Mass media | 2.64 | 1.23 | | 0.814 |
| | | 2.2 | A2 - Internet media | 2.59 | 1.28 | | |
| 3 | Knowledge | 3.1 | K1 - Earthquake | 3.40 | 1.20 | | 0.656 |
| | | 3.2 | K2 - Family | 3.55 | 1.21 | | |
| | | 3.3 | K3 - Transportations | 3.10 | 1.22 | | |
| | | 4.1 | Mobile phone (voice, messages) | 2.72 | 1.34 | | |

⁹ It was commissioned by one of the largest professional research companies in Japan which has a survey panel of more than a million people across the country. <http://www.macromill.com/qManage/macromillQuality.pdf>

¹⁰ Tokyo and the 6 surrounding prefectures – Ibaraki, Tochigi, Gunma, Saitama, Chiba and Kanagawa

¹¹ A commonly used measure of reliability between multiple measurements of a variable (George & Mallery, 2013).

| | | | | | | | |
|--|--|-----|--------------------------------|--------------------|------|--|--|
| | | 4.2 | Mobile phone (Internet) | 2.32 | 1.21 | | |
| | | 4.3 | Television | 2.95 | 1.36 | | |
| | | 4.4 | Radio | 2.47 | 1.37 | | |
| | | 5.1 | Stress from crowd | 4.38 ¹² | 0.49 | | |
| | | 5.2 | Physical stress | 4.00 | 0.90 | | |
| | | 5.3 | Fear from aftershocks | 4.28 | 0.84 | | |
| | | 5.4 | Other people's behaviour | 3.52 | 1.01 | | |
| | | 5.5 | Information from station staff | 2.96 | 1.23 | | |

5.2 Result analysis

The presence of collective resilience among the stranded commuters – hypothesis H1 – was tested by one-sample t-test and bivariate correlation. One-sample T test was used to examine if the means of the four factors that represent collective resilience – C1, C2, C3 and C4 – were significantly above the mid-point level. Then bivariate correlation was performed to check if these four factors are positively related to one another. The results are summarised in Table 2.

Results of the one-sample t-test show that the means of 'C1 shared identity' and 'C2 interdependence' are significantly above the mid-point level of 3. At the same time, the means of 'C3 helped others' and 'C4 helped by others' are below. In other words, most of the stranded commuters did feel a sense of shared identity and interdependence. However, not many of them actually helped or were helped by others. That being said, the bivariate correlations between these factors indicate that they are all strongly and positively related. Thus, we argue that hypothesis 1 is partially supported.

Table 2 Hypothesis H1 - Collective resilience

| Variable | One-sample t-test | | | | Pearson correlation **. Correlation is significant at the 0.01 level (2-tailed). | | | |
|-----------------------|-------------------|-----|-----------------|-----------------|---|--------|--------|--------|
| | t | df | Sig. (2-tailed) | Mean Difference | C1 | C2 | C3 | C4 |
| C1 - Shared identity | 42.697 | 257 | .000 | 3.25 | 1 | .456** | .411** | .369** |
| C2 - Helped others | 35.644 | 257 | .000 | 2.76 | | 1 | .536** | .429** |
| C3 - Helped by others | 33.854 | 257 | .000 | 2.54 | | | 1 | .387** |
| C4 - Interdependence | 44.321 | 257 | .000 | 3.19 | | | | 1 |

The effects of ICT on collective resilience - hypotheses H2, H3, H4 and H5 - were examined using structural equation modelling (SEM). A SEM model (Figure 4) was constructed to represent the path model shown in Figure 3. In this model, latent variable is represented by an oval shape; observed variable is represented by a rectangle; error term is represented by a

¹² This value is distorted because only the respondents who had answered 4-agreed or 5-strongly agreed were included.

circle; the relationship between different variables is represented by an arrow. Considering that the four ICT types are not mutually exclusive, thus they are all co-varied. Similarly, 'knowledge' and 'advice' are also co-varied because they are also assumed to be non-mutually exclusive.

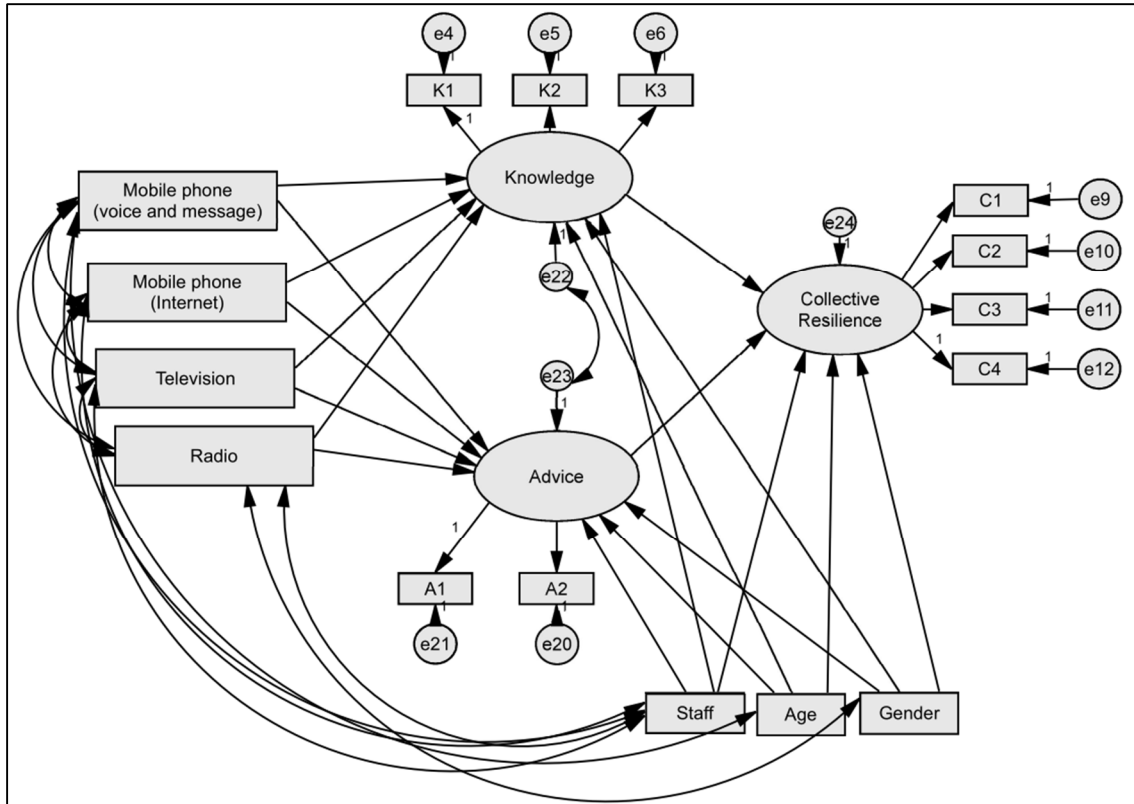


Figure 4 SEM model

The resultant model fits indicators (CMIN/DF=1.812; CFI=0.949, GFI=0.936, AGFI=0.890, RMSEA=0.056, PCLOSE=0.234) indicate that the model is statistically acceptable¹³. The hypotheses were tested by examining the standardised estimate and its corresponding significance between different variables. The results are summarised in Table 3.

First of all, the result shows that 'advice' has a strong, positive and significant effect on 'collective resilience'. Thus, hypothesis H2 is supported. In other words, advice on what to do the stranded commuters received from mass media and the Internet increases their level of collective resilience. That is, ICT information and advice can assume the role of a leader to keep individuals to remain in the same state of collective resilience.

Secondly, the results show that 'knowledge' has a negative and significant effect on 'collective resilience'. Therefore hypothesis H3 is also supported. It should be noted that this does not mean that knowledge of the disaster makes people less helpful to each other. Rather it implies that knowledge can reduce the complexity of the issue – the disaster in this case – and let the commuters to make their own decisions. Thus, it reduces their interdependence on others and reduces the risk of herd behaviour.

¹³ Based on the model fits indices recommended by (Gaskin, 2012).

Thirdly, for hypotheses H4-1 to H4-4, the results show that all four ICTs have a positive effect on 'advice', thus they are all supported. Among different types of ICT, mobile phone (voice and messages) has the strongest influence, followed by radio, mobile phone (Internet) and television. Therefore, it is logical to assume that personalised communications such as mobile phone and mobile Internet are the more effective mean to obtain advice than broadcasting media. However, why radio is ranked second will need further investigation.

For hypotheses H5-1 to H5-4, the results show that mobile phone (voice and messages) and television have a significant positive effect on 'knowledge'. However, mobile phone (Internet) and radio have no direct effect at all. Therefore, hypotheses H5-1 and H5-3 are supported but H5-2 and H5-4 are not. In this case, 'knowledge' is consisted of three factors; knowledge of family's safety status, information about the earthquake, and information about the public transportation's service status. With this in mind, it is logical to interpret that mobile phone is the most effective for the former, and television is for the latter two factors. The reason why mobile phone (Internet) and radio have no direct effect is probably due to their low usage.

Table 3 Hypotheses H2, H3, H4 and H5

| | Parameter | | | Standardised estimate | Significance | Result |
|--|-----------------------|------|-----------------------------------|-----------------------|--------------|---------------|
| H2 | Collective Resilience | <--- | Advice | 0.834 | *** | Supported |
| H3 | Collective Resilience | <--- | Knowledge | -0.385 | ** | Supported |
| H4-1 | Advice | <--- | Mobile phone (voice and messages) | 0.299 | *** | Supported |
| H4-2 | Advice | <--- | Mobile phone (Internet) | 0.181 | ** | Supported |
| H4-3 | Advice | <--- | Television | 0.167 | ** | Supported |
| H4-4 | Advice | <--- | Radio | 0.272 | *** | Supported |
| H5-1 | Knowledge | <--- | Mobile phone (voice and message) | 0.340 | *** | Supported |
| H5-2 | Knowledge | <--- | Mobile phone (Internet) | -0.145 | NS | Not supported |
| H5-3 | Knowledge | <--- | Television | 0.321 | *** | Supported |
| H5-4 | Knowledge | <--- | Radio | 0.082 | NS | Not supported |
| *** ≤0.001; ** ≤0.05; NS = Not significant | | | | | | |

6. Discussions and conclusion

In time of crisis, instead of panicking, in most cases people in crowds are capable to remain calm and to provide mutual supports. Referred as collective resilience, this capability can greatly increase a society's capacity to withstand external shocks such as natural disasters. That being said, in rare cases, crowd disasters such as mass panic and stampedes had also occurred.

Critical transitions theory explains that under external stress, a highly homogeneous and interconnected group will remain in one state collectively. For example, people in crowds to remain calm and orderly in the wake of an unexpected external shock. However, when the level of external stress reaches the group's threshold, even a similar force can propel the whole group to shift to an alternative state rapidly. For example, mass panic. Therefore, a more homogeneous and interconnected group of people can withstand a stronger level of external stress, as in the case of collective resilience. At the same time, such characteristics can also build up the risk of a sudden shift such as mass panic in a crowd disaster.

This study uses the case of the large crowds of stranded commuters amassed near major stations in Tokyo on 11 March 2011 as the case study. The preliminary result analysis has demonstrated the presence of collective resilience as well as the roles and effects ICT have in it. First of all, the stranded commuters felt a sense of shared identity and interdependence despite they were under high level of external stress. For example, stress from the intense crowd density, tiredness and fear from aftershocks. Thus, based on the literature, we argue collective resilience had contributed to their overall calmness and orderliness. In addition, the results show that ICT can play two different roles in collective resilience.

The first is the role of a leader, ICT information and advice on what to do can keep individuals to remain together to withstand the external stress. As in this case, the stranded commuters felt a sense of shared identity and interdependence. In other words, ICT information can increase the level of collective resilience by guiding individuals to follow the same advice. That being said, it should be noted that this effect can also have negative outcomes. For example, false information and rumours can lead to mass panic or hysteria (Zhen, et al., 2008; Helbing & Mukerji, 2012). In this case, the results show that personalised communications such as mobile phone and mobile Internet have a strong direct effect on the amount of advice the commuters had received. However, as Nogami & Yoshida (2014) point out, disaster rumours are also more likely to spread over personalised communications and the Internet. Therefore, in time of crisis, for government authorities, it is important to monitor the type of advice being circulated over different media.

The second role of ICT in collective resilience is that by providing knowledge of the situation, it can reduce the risk of mass panic or herd behaviour. For instance, the results show that knowledge of the disaster has a negative effect on the level of collective resilience. This does not mean that knowledge makes people less supportive to one another. Instead, it demonstrates that ICT information allows people to make their own decisions rationally. For example, the stranded commuters' decision on when and how to return home were affected by the level of information they had (Takada, et al., 2012; Hara, 2013). Therefore, by providing the correct knowledge of the situation, ICT can reduce the level of interdependence of a group.

Subsequently it can reduce the chance of a sudden shift to an undesirable state. In other words, reduce the chance of the occurrence of mass panic or herd behaviour.

In conclusion, it should be noted that these findings are based only on the preliminary result analysis. Although the results are in line with the literature, further analyses are required to confirm their reliability and validity. In addition, considering that the survey was conducted four years after the disaster. Although some says that March 11 has become an unforgettable day for most Japanese (Ueno, 2013), the responses might still be biased or distorted. Therefore, additional investigations on other qualitative sources are necessary to strengthen the findings. Finally, more in-depth investigations on the related policies are also necessary in order to extend the implications.

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