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Design of a Resilient Information System for Disaster Response: Lessons from municipal government systems under the Great East Japan Earthquake crisis

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Abstract

The devastating 2011 Great East Japan Earthquake showed up the vulnerability of Information and Communication Technology (ICT) for sustaining life during and soon after a disaster. This paper first addresses issues related to the design of information systems (IS) based on a field study and survey results that assess the damage inflicted upon the municipal government information system during the earthquake. Then, a set of design principles is proposed that improve the handling of similar unexpected catastrophic events in the future.

From the field study, three key IS problems are defined; (1) ICT failure due to unexpected, (2) diversity of damage situations forcing creative and autonomous responses in the field and (3) lack of compatibility among efforts in the field hindering a smooth return to normal business. It is impossible to build a system that never fails. Rather, we should design a resilient IS that quickly gains essential capabilities to perform critical post disaster missions and to smoothly return to fully stable operation thereafter. Essential for municipalities is the capability to conduct disaster relief operations. Since these problems occurred chronologically, this paper proposes a three-stage model (in advance, initial response and recovery) to design resilient IS. The notion of frugal IS (Watson et al. 2013) that emphasizes the use of minimal resources to meet preeminent goals was adopted as a foundation of design principles.

A frugal IS supports a creative response in the field by adopting open and standard technologies for our conventional systems so that data from these systems can be extracted and used by creatively developed systems in the field following a disaster. In addition, it encourages the use of residents' devices, rather than government prepared terminals as a foundation of frugal IS. This promotes the collaboration of people using materials readily available in times of disaster.

Keyword: Disaster management, Resilient, Information systems design, Municipal governments, Frugal IS

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I would like to express my sincere gratitude to Dr. Richard T. Watson. He made me decide to proceed to the Ph.D program, and he is the reason why I wrote this paper in English because I wanted to be supervised by him. He accepted me to stay in Athens, Georgia for a half year for my dissertation and taught me a lot. I learned what Management of Information Systems (MIS) is. Not perfectly, but I found my future direction that is designing policy based on IS discipline. He also taught me what academia is. Everything I felt in Athens was an eye-opening experience. I can say he opened my world to academia. I would not be here if I had not met him. He advocated the notion of frugal IS that is the theoretical foundation of this research.

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Part One

Lessons from the Past

"The empirical sciences are systems of theories."

(Popper 2002)

"Scientists try to identify the components of existing structures.

Designers try to shape the components of structures."

(Alexander 1969)

Chapter One

Force for Changing Perception

The Great East Japan Earthquake, Japan's largest in recent times, occurred in 2011 and caused severe damage to a very wide area, with the tsunami wreaking havoc beyond any prior expectations. The earthquake and subsequent tsunami revealed the vulnerability of Japan's Information and Communication Technology (ICT) infrastructure. It greatly affected the recovery process and more than likely increased the loss of life. Such massive disasters will likely become more common, as the number of natural disasters in the world is increasing.[1] There were three times as many natural disasters between 2000 and 2009 as there were between 1980 and 1989.[2] Given the importance of ICT to the functioning of modern society and its evident vulnerability, we must rethink how we design ICT systems to deal with future disaster situations.

This paper addresses issues related to the design of information systems and how the design may enhance the handling of future and unexpected disasters or similar catastrophic events. It focuses specifically on systems resilience, the measure of a system's persistence and the ability to absorb disturbances while maintaining the existing relationships between system entities (Holling 1973). Information systems (IS) research is missing, I believe, a methodology for the design of resilient systems that support the relief and recovery stages of a disaster. We have become dependent on ICT for the performance of nearly all activities in advanced economies,

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[1] Last accessed Sep. 3rd 2014, at http://www.emdat.be/natural-disasters-trends

[2] Last accessed Sep. 3rd 2014, at http://www.accuweather.com/en/weather-blogs/climatechange/steady-increase-in-climate-rel/19974069

and disasters illustrate the fragility of this dependence. They shake our confidence in technology.

1-1: Who should play a role in disaster relief?

According to the literature on disaster management, the foremost response to a disaster comes from local organizations (Drabek 1985). 'Local' may refer to government, or voluntary and private organizations, but it is local government which owns "the first line of official public responsibility (McLoughlin 1985)." That is certainly the case in Japan, where municipal governments are predominantly in charge of running disaster relief operations. This research, then, focuses on how municipal governments use IS for a current and future disaster situation.

Within the administrative structure of the Japanese government, municipalities occupy the third rung. National Government occupies the top tier, followed by prefectural governments (47 of them) and municipal governments (1,742 cities, towns and villages as of January 1, 2014). The size of municipal governments varies enormously. Big cities such as Osaka and Yokohama each have a few million residents. Small villages have less than a thousand. There are several types of municipal governments, such as cities (requiring a population of over 50K), towns (variously defined in prefectures), and villages and special wards. Legally, the function of these governments is to provide a variety of services to their residents but above all they have the obligation to maintain resident information, i.e., the data that serves as the foundation for government. Prefectures, on the other hand, are defined more loosely as wide area government.

Both prefectural and municipal governments conduct disaster relief operations such as helping disaster victims, securing the lives and safety of their residents, and supporting the recovery of local business activities. Commonly these duties are defined in the local disaster management plan. In addition, prefectural and municipal governments are expected to function as command centers for various support activities undertaken by the Self-Defense Forces, the Red Cross, and other public and private organizations.

The primary operations of municipal governments following the Great East Japan Earthquake were:

- Confirming the whereabouts and safety of residents
- Providing residents with information
- Establishing and operating evacuation centers
- Transporting and managing relief goods
- Supporting evacuees and creating evacuee lists
- Issuing disaster victim certificates

Once a disaster happens, inquiries about confirming the whereabouts and safety of residents from outside of the area concentrate on municipalities. In this sense, during a disaster, municipalities are virtually the sole source of information concerning damage and recovery for its residents. Therefore, municipalities should collect accurate information and be in a position to transmit it effectively. One major operation that municipalities should deal with is to establish evacuation centers. Normally public facilities such as community centers and public schools like elementary and junior high schools turn into evacuation centers. Municipalities' officials subsequently engage in operations of the evacuation centers and imperative needs are to create evacuee lists to respond to the inquiries. Since people in evacuation centers moves to other centers all the time, tracking people's arrivals and departures becomes essential. At the same time, management of relief goods that are sent from all over the world is on the list of municipalities' operations. After a situation settles down, municipalities are in charge of issuing disaster victim certificates. This certificate is used as proof of a disaster victim and is needed to get disaster support services from the national and prefectural governments.

These tasks are different from the daily operations of municipal government, and other tasks were suspended to meet the impending and mounting needs of citizens (Sakurai et al. 2014). In the initial phase, immediate response measures in the municipalities that experienced major devastation focused on saving lives and guiding survivors to evacuation centers, with little priority given in some areas to reopening resident service counters though there was a sense of urgency regarding the need for access to residents' personal information in order to facilitate rescue operations (Sakurai et al. 2013).

Documenting personal information is an extremely labor-intensive task and most of the municipalities made significant efforts to complete this unexpected post-disaster duty.

1-2: Importance of a disaster management strategy

To achieve disaster relief operational goals, undoubtedly we should recognize the importance of disaster management. The Federal Emergency Management Agency of the United States (FEMA) applied an "Integrated Emergency Management System (lEMS)" approach to develop, maintain, and manage an efficient and cost-effective emergency management capability (McLoughlin 1985). This IEMS is composed of four stages, that is:

*Mitigation: Activities that reduce the degree of long-term risk to human life and property from natural and man-made hazards

*Preparedness: Activities that develop operational capabilities for responding to an emergency

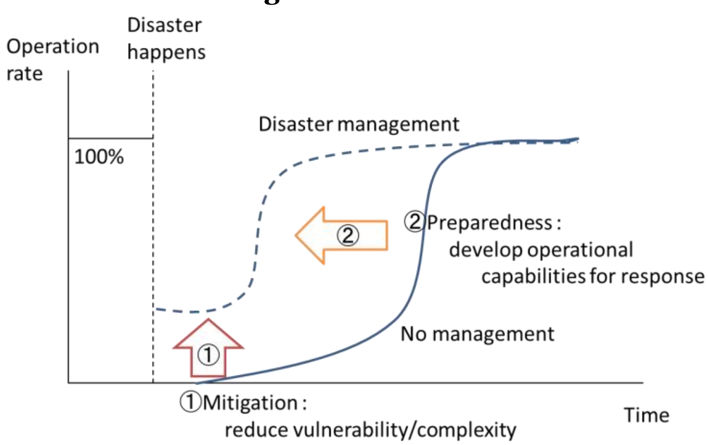
*Response: Activities taken immediately before, during, or directly after an emergency that save lives, minimize property damage, or improve recovery

*Recovery: Short-term activities that restore vital life-support systems to minimum operating standards and long-term activities that returns life to normal

'Mitigation' has the purpose of reducing vulnerabilities of the society. It includes building codes, disaster insurance, land-use management, risk mapping, safety codes, and tax incentives and disincentives. 'Preparedness' intends to develop capabilities to deal with disaster situations. For example, emergency operations plans, warning systems, emergency operating centers, emergency communications, emergency public information, mutual aid agreements, resource management plans, and training and exercises are considered to be preparedness tools. 'Response' is an element to which normally the biggest attention is paid. Components of the response stage are, emergency plan activation, activation of emergency systems, emergency instructions to the public, emergency medical assistance, manning emergency operations centers, reception and care, shelter and evacuation, and search and rescue. Lastly, 'Recovery' process includes debris clearance, contamination control, disaster unemployment assistance, temporary housing, and facility restoration. These four stages are discussed in financial and public health aspects of disaster management as well (Settle 1985; Shoaf et al. 2000).

The following diagram shows relationship between mitigation and preparedness.

Figure 1: The effects of disaster management



Source: Ministry of Internal Affairs and Communications "Guideline to draw up ICT-BCP for local governments" (August 2008) http://www.soumu.go.jp/main_content/000145527.pdf, p.5, partly modified by the author

We have no capability to stop a natural disaster, but the degree of working on mitigation decides the damage level of a disaster. In this sense, mitigation becomes a foundation of a disaster response. In other words, it aims to lessen the complexity of the situation. This intends to keep a disaster situation organized and realize smoothly preparedness for effective responses.

Implicit in much of the existing disaster planning literature is the assumption that preparedness and effectiveness are related positively and significantly. That is, the better prepared an organization or community is for a disaster event the more effective its response (Gillespie et al. 1987). Preparedness is critical to ensure that planned events proceed smoothly and unplanned events cause minimal disruptions (Ng et al. 2012). An important aspect of preparedness is planning. Emergency response plans within the chain of command and with given agency roles are essential (Gebbie et al. 2002). They stressed the importance of regular drills asserting that "plans that are never practiced or that are poorly understood will probably be useless."

On the other hand, Quarantelli (1981) points out that "realistic disaster planning requires that plans be adjusted to people and not that people be forced to adjust to plans (Gillespie et al. 1987)." A written emergency plan does not guarantee that actual operations will be effective. However, the process of planning that leads to the development of a written plan is extremely valuable (McLoughlin 1985). The process of planning gifts us knowledge of the community-area and resources at risk of damage and an assessment of the loss that would result from the occurrence of the event. The plan can identify hazard areas, such as flood plains, fault zones, landslide areas, and hazardous waste sites, and guide concentrated development away from them by designating them for open space or low-density uses, such as parking or recreation (Godschalk et al. 1985). A disaster management plan in good combination with mitigation is significant both before and after a disaster happens.

1-3: Local government's disaster management plan

The Japanese public disaster management plan is normally based on two steps.

The first step, from a broad perspective of disaster prevention, mandates that each municipality draw up its local disaster prevention plan. In general, then, this plan specifies the scope of action to be taken by any relevant organization during a disaster, such as setting up a disaster response headquarters and confirming the safety of residents. Some plans also clarify the role of each operational division. After the disaster response headquarters is set up, many of the municipalities dispatch personnel for tasks such as operating the evacuation centers and transporting goods under instructions from those headquarters. This plan also provides guidelines on how to equip facilities and store relief supplies, how to raise resources which are required to conduct disaster relief operations, how to educate residents or conduct disaster drills with them, how to collect and provide information related to the management of disasters, and so on.

The focus of this plan is to prevent devastating damage and reduce risks during a disaster. Furthermore, it is to make people, facilities and organizations robust. This means, the plan describes the process of reducing vulnerability as is realized by making entities robust. For example, to provide residents with access to information, the national government has allocated a large budget to developing channels of communication such as external public announcement systems and internal receivers, and an emergency alert system. According to an annual budget report by the Ministry of Internal Affairs and Communications, over two billion US dollars were spent in 2013 and 2014 to promote these ongoing projects. These systems are considered to be strong enough to withstand a disaster.

The second step involves drawing up a business continuity plan (BCP). BCPs seek to eliminate or reduce the potential impact of a disaster before that condition occurs (Cerullo et al. 2004). As society becomes more and more dependent on its information technology infrastructure, the risks of business interruption also keep expanding (Cerullo et al. 2004). The problem with the notion of the BCP is, of course, that it intends to continue ”business as usual” at times of extreme stress. It lacks the recognition that a disaster management operation of municipalities is essentially a different type of operation. As was mentioned previously, the top priority of public organizations in a disaster situation is to save lives and help its residents. A BCP in the business field does not usually consider such disaster relief operations. Basically, a disaster relief operation is an extremely labor-intensive task and though most of the municipalities make significant efforts to accomplish its provisions following an unexpected disaster, officials find it extraordinarily demanding.

After the Great East Japan Earthquake, the national government drew up a new guideline for the BCP that focuses on municipalities' responses immediately after a disaster. It sets out to show how to prepare disaster-proof technology to support disaster relief operations. However, this misses explaining how to respond to unpredictable disasters. A planned type of strategy should be distinguished from an entrepreneurial one (Mintzberg et al. 1985). A planned strategy means "precise intentions exist, being formulated and articulated by central leadership." That kind of strategy does not expect any surprises. It tries to plan everything in advance of a calamity. On the other hand, an entrepreneurial strategy intends to adjust to unexpected, new opportunities arising from a given situation; "entrepreneurial strategies are relatively deliberate but can also emerge unexpectedly." Is it really possible to prepare every response in advance? Here, adaptability to unexpected opportunities should be considered. The question, then, is how to accomplish that adaptability.

To achieve it, we have two choices: one is to avoid major failures by managing demanding technologies to that effect, and the other is to maintain the capacity for facing unpredictable contingencies (La Porte 1996; Rochilin 1993). The former is a traditional approach, which tries to make entities robust. The latter is based on the likely occurrence of unexpected events. This study explores how to design information systems to handle future and unexpected disasters or similar catastrophic events. The answers to respond to these choices are discussed in the following chapters.

1-4: Structure of this paper

This research reports on two case studies, and a survey result completed following the Great East Japan Earthquake. The first case is based on structured interviews conducted in 13 municipalities. The second is based on interviews in Tagajo City. Two cases investigated the effects of the earthquake on ICT local administration. These analyses lead us to realize that it is impossible to build a robust system that never fails and to recognize the importance of creative field responses. We need resilient systems that recover their core functions flexibly and quickly following a disaster. Such systems should enable a creative and autonomous response in the field immediately after a disaster. The objective of embedding such creative response in the design of IS does not only give an IS the capability to recover core functions but also to meet the diversity of needs following a disaster. A hypothesis here is the notion that frugal information systems (Watson et al. 2013) support the realization of a resilient information system that can function following a disaster. Generalization of design principles derived from the case studies is tested by a field test and a questionnaire survey.

This paper is structured into following two parts: (1) analyzing the Great East Japan Earthquake and defining key problems in the field, and (2) deriving solution design for building a resilient information system which is supposed to solve the problems. The former part includes the literature review to organize basic thinking about this issue. The latter part includes evaluation of concepts. I believe development of methodologies to implement a resilient information system will contribute to an area of IS research that has been rarely discussed before.

Chapter Two

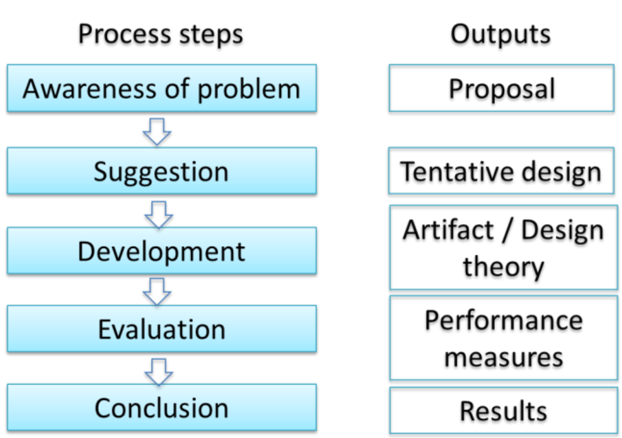
Methodology

Since there is a need for new design principles in building information systems (IS) that are able to respond to a large-scale disaster, this research applies a design science methodology. It aims to derive design requirements and systems features from practical observations. Design science approach begins with the notion of "the sciences of the artificial" which is advocated by Herbert A. Simon (1969). Design is defined as "the use of scientific principles, technical information and imagination in the definition of a structure, machine or system to perform pre-specified functions with the maximum economy and efficiency (Walls et al. 1992)."

In an industry of developing new products, the importance of careful observation is recognized as well. Direct observation and good understanding of people's needs and wants leads innovation activities with design principles to increase the value of a product (Brown 2008).

The following diagram shows general research process of a design science methodology.

Figure 2: Design science research (Baskerville et al. 2009; Beck et al. 2013; Kuechler et al. 2008)



Design science research is a problem-centered approach (Peffers et al. 2007). Once a main problem is defined, an IS design theory (Brohman et al. 2009; Walls et al. 1992) is developed, and evaluated. Evaluating a theory means to compare a system's functionality with objectives of suggested solutions (Peffers et al. 2007). This comprises quantitative performance or measures of the system's availability. To conduct strong and productive research, triangulation of research methods should be promised (Jick 1979). This indicates both qualitative and quantitative methods play a vital role in good research. Qualitative research methodologies are quite valuable when it aims to understand social settings (Myers 1997). Thus, this research applies case study methodology for problem awareness and survey methodology for evaluation.

2-1: The foundation of research in information systems

"Information systems improve an entity's ability to attain its goals (Watson 2014)."

IS research differs from other disciplines in the way it aims to understand both physical objects and human behavior as knowledge artifacts (Gregor 2006). At the same time, understanding information technology itself is insufficient, IS research should focus more on improving IT practice (March et al. 1995). IS knowledge becomes meaningful when it is put into real world (actions and decisions) (Davis et al. 1985). This process is conducted using special tools and approaches such as data modeling, systems analysis and design which makes IS research unique (Watson 2014). One purpose of these activities is to increase the amount of certainty (Mumford 2003), with theories and experiences derived from research. This means, in other words, to improve a system's ability. To achieve its purpose, the first thing we should target is to understand deeply components of structures (Alexander 1969) existing in this society.

Since IS research is not only an academic but also a professional endeavor, it should have both technological and management aspects. Technological discussion requires description of systems to be implemented in an organizational context, and management discussion needs to determine how they used in the same organizational context (Hevner et al. 2004). We can see this 'context' a similar meaning as 'components' by Alexander's. In addition, generalization of theories in different settings (contexts) (Lee et al. 2003) to apply research outcomes for other situations nurtures further understanding of structures of the society.

Generalizing a theory has been traditionally required by positivism. Positivism research tries to do reasoning about future phenomena with testing hypotheses and theories (Orlikowski et al. 1991). On the other hand, interpretive research attempts to understand a context of the information system and the process of information systems' affection to its context (Klein et al. 1999). It is believed that to understand the deeper structure of a phenomenon from an interpretive perspective brings more benefit than attempts to generalize a theory to other settings (Orlikowski et al. 1991). However, a theory plays an important role in connecting the natural and the social world, and that connection is significant in guiding IS design (Gregor 2006). It is certainly true that IT artifacts turn out to be useful for solving problems only with clear requirements (Beck et al. 2013), moreover, new ideas and theoretical developments are demanded to derive requirements of IS. These are realized by deep exploration of the philosophical issues (Rivard 2014).

An IS design theory must employ the following three characteristics (Markus et al. 2002): (1) working process, (2) users' work context, and (3) information requirements. Exploring the reality to lead to a deep understanding of phenomena and efforts to generalize theories that fulfill the above characteristics should be achieved together.

2-2: Design science research (DSR) as a problem-centered approach

A method that can achieve high understanding of the reality and generalize theories simultaneously is a design science approach.

The design science paradigm has its roots in engineering, and thus its aim is problem solving (Hevner et al. 2004). Design science is concerned with creating artifacts to achieve its goals while natural science is concerned with explaining how and why things are (Simon 1996).

This approach is similar to soft systems methodology (SSM) that was developed by Peter Checkland (1990). SSM regards a process of inquiry as a system while conventional system thinking takes the world to be systemic. With regard to a product, design refers to "a plan of something to be done," however, design process indicates "to plan the parts of structure (Walls et al. 1992)." What this methodology aims is to solve particularly situated problems by providing new ways to develop or improve organizations through the design of artifacts. In other words, SSM is more practically oriented with comparison to DSR which focuses more on generalized problems (Baskerville et al. 2009). This explains a huge difference between SSM and DSR. Primary differences between SSM and DSR are described in table 1.

Table 1: Comparison of characteristic of DSR and SSM (Baskerville et al. 2009)

Characteristic	**DSR**	**SSM**
Orientation / Method for	Research	Practice
Goal	Problem solving	Problem solving
Specificity	Generalized	Situation specific
Design role	Invention / generative	Application or (invention and application)
Outcome	Design theory or artifact shown to have utility	Situated organizational improvement

Since DSR intends to sublime problems to be generalized, it can produce concepts, constructs, and models, as well as artifact instantiations (March et al. 1995). In other words, DSR delivers the following as its output: design, evaluation, generalization, and theorization of the IT artifact (Gregor 2006; Gregor et al. 2007; Orlikowski et al. 2001).

While the purpose of a theory is generally "prediction and/or explanation of a phenomenon" (Dubin 1969) and it should be developed through incremental empirical testing (Kuhn 2012), design theories' characteristics are following (Walls et al. 1992):

(1) Design theories must deal with goals as contingencies

(2) A design theory can never involve pure explanation or prediction

(3) Design theories are prescriptive

(4) Design theories are composite theories that encompass kernel theories from natural science, social science and mathematics

(5) While explanatory theories tell “what is,” predictive theories tell “what will be,” and normative theories tell “what should be,” design theories tell “how to/ because”

(6) Design theories show how explanatory, predictive, or normative theories can be put to practical use

(7) Design theories are theories of procedural rationality

In an information systems’ research field, theories should integrate explanatory and predictive into design and action/practical use which explains “how to do something (Gregor 2006),” and defines a process of solving a particular problem.

As it is shown in figure 2, the process of design science approach is: (1) problem identification and motivation, (2) define the objectives for a solution, (3) design and development, (4) demonstration, (5) evaluation (Peffers et al. 2007). The objective of design science approach is to show utility which is based on the clear identification of what can contribute to the archival knowledge (Hevner et al. 2004). To clarify its utility, design science research put emphasis on iteration between design (development) and evaluation (experiment) to develop methods and artifacts (Kuechler et al. 2008). As it is discussed previously, scholarly contributions of DSR should appears in both practical relevance and theoretical contributions (Beck et al. 2013).

2-3: Case study for theory building

As DSR aims to derive design theory through practical problems or observations, its research activities take an inductive approach that means analyzing deep phenomena and creative works to describe the world in a new way. In order to find new ways to draw our society, the only effective manner is doing detective work well with creative leaps (Mintzberg 1979). Therefore, this research takes a case study methodology for its detective work. It may characterize this as an application of theory building from cases (Eisenhardt et al. 2007) on design principle, and verification of the principles.

A natural disaster is set as a main situation we think in this research of how we should handle ICT in a future unexpected event/disaster. Every disaster is likely different and have new situations emerging each time. A case study is a quite suitable approach for two directions of research. The first is in generating fresh or novel theory in a way which bridges abundant qualitative data to deductive research (Eisenhardt et al. 2007). The Second is in an area which few previous studies have been carried out (Benbasat et al. 1987).

IS literature does not give us many discussions to explain the way people should deal with IS in a disaster situation. As the literature says, discussions in contemporary IS research appear to be mainly based on the idea that IS reliability is achieved through the use of dependable technology (Butler et al. 2006). This means we need new concepts and theories when we discuss such a kind of situation. The process of building theory from case studies is: (1) selecting cases, (2) crafting instruments and protocols, (3) entering the field, (4) analyzing data, (5) shaping hypotheses, (6) enfolding literature, and (7) concluding (Eisenhardt 1989). Resources of data vary depending on a type of research. Normally, useful sources to collect data in case studies are: documentation (writing materials), archival records (personnel or financial records), interviews (open-ended or focused), direct observation (absorbing and noting details), and physical artifacts (devices) (Yin 2008). According to Yin, case study research is appropriate for answering how and why questions. These questions try to understand the complexity of the processes in a society. In addition to this, case studies have their strength in finding relationships between events that affect outcomes in a chronological manner because researchers can detect it in its natural setting. This helps researchers to evaluate independent and dependent variables without any controls (Benbasat et al. 1987).

Clarifying relationships between each datum leads IS requirements that can answer the following questions: "What utility does the new artifact provide?", moreover, "What demonstrates that utility? (Hevner et al. 2004)" These are kernel questions of design science research.

While this research takes case study methodology, mainly by structured interviews, to define the core problem, evaluation of a model will be conducted by a survey.

The following sections of this paper explore what the missing utility during the disaster response was, and new design principles to improve our capabilities to handle a future disaster situation.

Chapter Three

Empirical Research

The Great East Japan Earthquake occurred on March 11, 2011. It measured 9 on the Richter scale, which made it one of the most powerful earthquakes in recorded history. The tsunami reached 40 meters in height and hit the coastline, devastating cities and towns. The Fire and Disaster Management Agency reported 18,958 deaths, 6,219 injuries, and 2,655 missing as of March 2014. It also reported 127,291 houses completely destroyed and more than one million partially destroyed.

Collecting systematic data with a "well-defined focus" should be always realized when we go into the field (Mintzberg 1979). As we faced such an overwhelming calamity, Keio University decided to get into the field to understand what had happened and what was going on.

3-1: Data collection

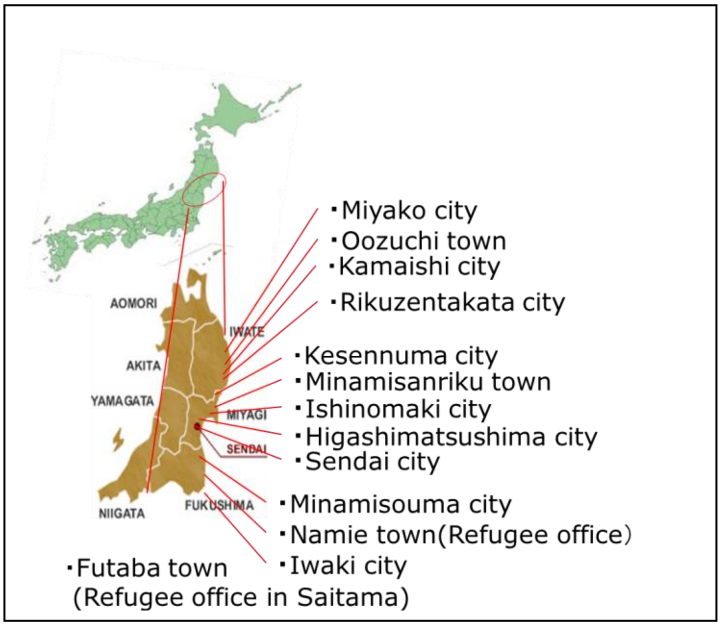
From November 2011 to February 2012, just eight months after the earthquake, Keio University conducted structured interviews with 13 municipal governments in the areas hardest hit by the earthquake (Sakurai et al. 2012). This research was a joint project with the Local Authorities systems Development Center, which was affiliated to Ministry of Internal Affairs and Communications. Research team of Keio University visited Miyako City, Oozuchi Town, Kamaishi City, Rikuzentakata Town, Kesennuma City, Minamisanriku Town, Ishinomaki City, Higashimatsushima City, Sendai City, Minamisouma City, Iwaki City, and the refugee offices in Namie Town and Futaba Town (Table 2 and Figure 3). These municipalities are located in the prefectures of Iwate, Miyagi, and Fukushima. In each municipality, our research team had two hours for the interview (see appendix-1 and 2 for interview questionnaire and its report).

Table 2: Municipalities interviewed and interview date (Sakurai et al. 2012)

Municipalities surveyed		Departments visited*	Interview date
Iwate Prefecture	*Miyako City*	Administration Planning Dep., Planning Div., Information Processing Promotion Office	December 16 (Fri), 2011
	Rikuzentakata City	Planning Dep. Collaboration Promotion Office., Administration Dep., Administration Div. (telephone interviews)	November 29 (Tue), 2011
	Kamaishi City	Administration Planning Dep., Public Affairs Division, Information Processing Promotion Section	December 15 (Thu), 2011
	Otsuchi Town	Disaster Recovery Bureau, Recovery Measures Promotion Office and Disaster Recovery Bureau, Information Processing Promotion Office Note: The survey also covered employees from the Finances and Planning Division, Yahaba Town, Iwate Prefecture, who were sent for relief work.	December 15 (Thu), 2011, January 19 (Thu) and January 20 (Fri), 2012
Miyagi Prefecture	*Sendai City*	Administration Planning Bureau, Information Policy Department, Information Policy Division	December 22 (Thu), 2011
	Ishinomaki City	Planning Department, Information Policy Division	November 25 (Fri), 2011
	Kesennuma City	Planning Department, Planning Policy Division, Information Processing Promotion Office	November 29 (Tue), 2011
	Higashimatsushima City	Disaster Recovery Policy Department, Recovery Policy Division, Information Processing Promotion Unit	November 25 (Fri), 2011
	Minamisanriku Town	Disaster Recovery Planning Division, Information Processing Promotion Section	January 20 (Fri), 2012
Fukushima Prefecture	*Iwaki City*	Administration Department, Information Policy Division	December 22 (Thu), 2011
	Minamisoma City	Administration Planning Department, Information Policy Division	December 13 (Tue), 2011
	Futaba Town	Saitama Branch, Residents Lifestyle Improvement Division and Administration Division	January 12 (Thu), 2012
	Namie Town	Nihonmatsu Office Administration Unit	December 9 (Fri), 2011

* Names of organizations are as at the time of the interview

Figure 3: Municipalities visited for interviews



The populations of the municipalities we visited vary from 2,000 to 70,000 (see appendix-4 for details of visited cities and towns). The main objective of the interviews was to formulate a standard business continuity plan (BCP) for local governments so that they might be better prepared in the event of future disasters. Literature bearing on this goal recommends that emergencies be managed along four stages, namely, mitigation, preparedness, response, and recovery (McLoughlin 1985; Settle 1985; Shoaf et al. 2000). Based on these notions, the structure of the interview was decided. There were questions on preparedness, the level of damage, and the recovery process of ICT equipment including power supply, network connectivity, information systems, and related facilities.

In order to provide an overview of the status of devastation at the municipalities surveyed, prior to analysis of the situation in each area, table 3 summarized information regarding the damage to each municipal government office building, relocation of resident service counters, damage to the relevant ICT division employees, loss of residential digital data, use of backup data, and earthquake resistance reinforcement measures taken over the past ten years.

From this information, it is apparent that the definitive effects of the tsunami, and not the earthquake, made it impossible to continue operations at all 13 municipal government office buildings. The quake resistance testing and proofing measures implemented by many of the municipalities over the period of the past ten years paid off.

Table 3: Damages suffered by the municipal government offices surveyed and relocation of resident service counters

(As of January 2012)

Municipalities surveyed		Damage to the government office building	Relocation of resident service functions	Damage to the ICT division employees	Earthquake resistance reinforcement measures taken over the past ten years
Iwate Prefecture	*Miyako City*	No structural damage First floor submerged	No	No damage	Not implemented Diagnosed as requiring reinforcement
	Rikuzentakata City	Totally submerged (3-storied building)	Yes	Damaged	Implemented in fiscal 2002
	Kamaishi City	Buildings 1 – 4 partially submerged	Yes	No damage	Not implemented Diagnosed as requiring reinforcement
	Otsuchi Town	Totally submerged (2-storied building)	Yes	Damaged	Not implemented
Miyagi Prefecture	*Sendai City*	No structural damage No flooding	No	No damage	Implemented in fiscal 2009
	Ishinomaki City	No structural damage No flooding	No	No damage	Earthquake resistance test completed
	Kesennuma City	No structural damage First floor of branch	Yes (Partially)	No damage	Not implemented

		office submerged			
	Higashimatsushima City	No structural damage No flooding	No	No damage	Implemented in fiscal 2004
	Minamisanriku Town	3-storied building washed away	Yes	Damaged	Details not available
Fukushima Prefecture	*Iwaki City*	No structural damage First story floor partially destroyed	No	No damage	Not implemented Plans currently being drafted for earthquake proofing
	Minamisoma City	No structural damage No flooding	No	No damage	Implemented in fiscal 2006
	Futaba Town	No structural damage No flooding	Yes	No damage	Not implemented
	Namie Town	No structural damage No flooding	Yes	No damage	15-year old building

As of January 2012, governments of five municipalities, Rikuzentakata City, Otsuchi Town, Minamisanriku Town, Futaba Town and Namie Town, were operating from temporary offices. Three of the government offices had to be relocated because the original buildings were submerged by the tsunami floodwaters, and two due to the nuclear accident at the Fukushima Daiichi nuclear power station (hereinafter referred to as the 'nuclear accident') operated by Tokyo Electric Power Company. In Kamaishi City, only resident service counters were moved to another location within city limits because the municipal government office, where resident service functions were earlier carried out, was destroyed by the tsunami and power supply in the area could not be restored immediately. Further, due to land subsidence and heaps of rubble in the vicinity, the area was deemed unsafe.

In Rikuzentakata City, Otsuchi Town and Minamisanriku Town, temporary office buildings were constructed close to the original locations and operations resumed there between March and April. Their server rooms were totally destroyed by the tsunami. It caused residential data loss, and its recovery was conducted from server hard disk drive and data stored at information processing systems subcontractors' facilities. Other 10 municipalities' server room survived the tsunami. However, in Futaba Town and Namie Town, the offices had to be relocated twice before operations were resumed at the current location (as of January 2012) and plans call for further moves or transfers to yet unspecified locations.

Apart from the comparative study of the 13 municipalities impacted by the earthquake, I undertook a second case study in another city. It is Tagajo City, located in Miyagi Prefecture, a city of about 60,000, where was flooded one third of the city area by the tsunami. In November 2011, a city officer of Tagajo City gave a presentation on the earthquake and ICT recovery process, reporting on the acute needs created by the disaster and the vital importance of an immediate and autonomous response in the field. Independently, I carried out a separate study of Tagajo City in August 2012, one and a half years after the earthquake.

Various problems were observed as time passed. In terms of chronological sequence, there were three key IS problems.

The *first* problem was infrastructure failure, especially power and communications. In many areas, electric power and connectivity were lost at the most critical lifesaving phase (i.e., immediately after the earthquake). Also, we discovered that up to four months were required to recover power and communications in some areas.

The *second* issue concerning the variety of IS needs surfaced after the infrastructure was restored. There was a diversity of IS needs depending on time and location. Information systems are essential to conducting immediate disaster relief operations. Based on such recognition, Japan had prior to the earthquake developed solutions in the form of package software to deal with disasters. Despite the existence of such planned solutions, municipalities were overwhelmed by the diversity of the needs. Instead of using the planned solution, several autonomous system developments emerged that filled the needs of municipal governments to meet the various demands of the residents.

The *third* problem was the confusion created by the multiple autonomous responses. While these systems were developed to meet the immediate needs, data compatibility among these systems was lacking. This caused delays in relief efforts and subsequently hindered recovery. In other words, fragmentation of data seriously damaged the efficiency and consistency of relief efforts.

In the following section, the paper explains these problems in detail and discusses an IS design for solving them and realizing a resilient information system.

3-2: Key IS problems in the disaster

As noted previously, the immediate problem after the earthquake was the failure of the supporting infrastructure needed to run information systems. Government buildings were generally robust and survived the tsunami. Nevertheless, their survival did not mean ICT survived. In addition, the physical destruction of servers meant that residential records were lost in some areas.

3-2-1: Unexpected ICT failure

Of the 13 municipal facilities we visited, the earthquake destroyed none, although the city office in Minamisanriku was washed away by the tsunami. Server rooms in 10 cities—except Minamisanriku, Rikuzentakata, and Otsuchi—survived the tsunami and remained functional as such; however, they were useless because of tsunami damage to power supply and network connectivity (Table 4 and 5), a possibility that had not been considered in disaster planning. With regard to ICT divisions, none of the 13 municipalities surveyed had drawn up action plans in case they would face unexpected power and network failure. Also, responses by the respective ICT divisions at the time of the disaster were mainly based on their own discretion.

Table 4: Timing of power supply resumption (at the municipal government office) (Sakurai et al. 2014)

Municipalities surveyed		Power resumption timing (Days after the disaster)
Iwate Prefecture	*Miyako City*	15 days
	Rikuzentakata City	3 days (only areas where emergency response headquarters were set up)
	Kamaishi City	Approx. 120 days (March 20 to server room and peripherals)
	Otsuchi Town	Approx. 20 days (to the Central Community Hall), approx. 45 days (to the temporary office)
Miyagi Prefecture	*Sendai City*	1 day (2 days to the Information Systems Center)
	Ishinomaki City	15 days
	Kesennuma City	6 days
	Higashimatsushima City	4 days
	Minamisanriku Town	Approx. 20 days (temporary office)
Fukushima Prefecture	*Iwaki City*	No power loss
	Minamisoma City	No power loss
	Futaba Town	No power loss
	Namie Town	1 day

Electric power and connectivity were lost at exactly the most critical lifesaving phase (i.e., immediately after the earthquake). Existing information systems were useless because almost all of the 10 affected municipal governments had never anticipated any long-term power failure. Although emergency power generators were available, there was not enough fuel to make them functional. No municipal government in the research had thought about the need to supply power to information system facilities. Supply was also limited to lighting and emergency equipment until fuel ran out. Recovery time varied depending on the damage and state of the progress of disaster relief operations. Up to four months were required to restore the power supply to the city office in Kamaishi. Although it may be close to impossible to anticipate the time required for power supply to be restored, measures must be implemented to clarify beforehand the tasks that must be carried out during a power failure and to create systems that will ensure uninterrupted power supply to essential ICT equipment. Initiatives must also be taken to prepare for other responses such as the relocation of some administrative functions in the event of prolonged power outages.

Post-disaster risks could potentially give rise to a number of adverse situations. In particular, a power failure will upset the operation of information processing systems and disrupt communication with the outside. Hence measures to ensure uninterrupted power supply are of utmost importance. Most of the municipal governments emphasized the need for a stable power supply.

Table 5: Status of communication means and timing of restoration (Sakurai et al. 2014)

Municipalities interviewed		**Status of usage *1 (March 11)**			**Timing of restoration (Days after the disaster)**		
		Land lines	Mobile phones*2	The Internet	Land lines	Mobile phones	The Internet
Iwate Prefecture	*Miyako City*	×	Δ (1)	×	Approx. 20 days	-	15 days
	Rikuzentakata City	×	×	×	Details unknown	7 days	120 days at the temporary office
	Kamaishi City	×	×	×	7 days	7 days	9 days

	Otsuchi Town	×	×	×	Approx. 45 days	9 days	Approx. 70 days
Miyagi Prefecture	*Sendai City*	○	Δ (2)	×	-	3 days	2 days
	Ishinomaki City	×	×	×	15 days	15 days	15 days
	Kesennuma City	×	Δ (3)	×	10 days	Approx. 10 days	6 days
	Higashimatsushima City	×	×	×	6 days	Approx. 20 days	6 days
	Minamisanriku Town	×	×	×	Approx. 20 days	Approx. 20 days	Approx. 20 days
Fukushima Prefecture	*Iwaki City*	○	○	×	-	-	1 day
	Minamisoma City	○ (From March 12 ×)			8 days	8 days	8 days
	Futaba Town	○	Δ (4)	×	-	7 days	2 hours
	Namie Town	×	×	×	Details unknown	Details unknown	80 days

*1: Could not be used: ×, Could be used: ○, Could be used with some restrictions: Δ

*2: Information on the status of usage of mobile phones is as stated by the interview respondents. The status of usage of mobile phones immediately after the disaster and the timing of restoration varies by telecommunications service provider and area.

(1) Mobile phones could be used between only a few telecommunications service providers.

(2) Varies by telecommunications service provider and area.

(3) Could be used until around 10 p.m. on March 11.

(4) Could be used only to send and receive e-mails, not to make phone calls

Telecommunications were also disrupted as a result of the power outage. Also, many switching facilities were lost, and cables were damaged by the tsunami. Rikuzentakata, Otsuchi, and

Minamisanriku were forced to move to temporary offices because city offices were damaged or washed away by intruding water. The restoration of the Internet in these areas was slow compared to other municipalities. Satellite Internet base stations were sent to these areas almost one month after the disaster. Up to four months was required to resume normal Internet connectivity in Rikuzentakata. Among individuals, a mobile phone was the most widely used communication tool. Service was available in most areas until the batteries at cell tower sites began to discharge, with most running out by the following day (March 12). Conversation was mostly impossible, but packetized email systems could be used immediately after the quake. Many municipal government officials had learned of the coming of the tsunami with TV tuners on their private phones. Mobile phones were restored more quickly than landlines (fixed communication lines), but nevertheless cell sites were out of service from a couple of days to approximately two weeks.

The expectations of ICT divisions and the requisites for and processes towards recovery varied greatly along several variables. The variables included structural damage to government facilities, server rooms and loss of data. There were severe doubts as to whether power supply and network connectivity could be resumed immediately and whether communication tools such as cell phones would remain functional during the crisis. Another unknown was the degree of mass emergency evacuation to locations outside the affected area.

Also notable was the need for progressive adaptation in the situation. As the situation changed over time, requirements for dealing with it also changed. In the initial phase, immediate response measures in the municipalities that experienced major devastation focused on saving lives and guiding survivors to evacuation centers, with little priority given in some areas to reopening resident service counters (though there was a sense of urgency regarding the need for access to residents' personal information in order to facilitate rescue operations). Some ICT divisions even dispatched employees to do relief work, with just skeleton staff remaining in the office. At these municipalities as well, providing support to the affected people at various post-disaster stages was difficult without the use of ICT (including information systems). It became more than apparent that post-disaster expectations toward ICT divisions change as time passes.

The following is a typical timeline of responses, produced on the basis of activities conducted by employees of ICT divisions at the municipalities that were surveyed. Officials -

1) checked the condition of the servers and other equipment in the server room immediately after disaster struck;

2) confirmed resident whereabouts and helped with transporting goods and other tasks related to the operation of evacuation centers;

3) worked on restoring information processing systems, networks, and other related equipment within the facility after power supply was resumed;

4) studied the introduction of and developed information processing systems that can be used for disaster response activities;

5) worked to restore public data networks in the region.

While officials struggled to recover of ICT, whole municipal governments failed to share information and process data due to power loss and a shortage of personnel. All of this impacted negatively the five critical missions for life saving activities following any devastating disaster, such as 1) confirming the whereabouts and safety of residents, 2) establishing and operating evacuation centers, 3) transporting and managing relief goods, 4) supporting evacuees and recording status, and 5) issuing disaster-victim certificates. These are all disaster specific operations that require data from core municipal government ICT systems.

In fact, operations were carried out by traditional methods using pencil and paper. That made it very difficult to get any overview of new developments in different areas of the disaster zone and so hindered effective responses. Slow recovery of ICT hindered all other recovery processes. Clearly, lack of resilience in ICT proved to be a serious problem when municipalities tried to tackle disaster recovery operations. To operate disaster relief activities successfully, it is necessary to restore essential ICT infrastructure as soon as possible.

3-2-2: Crisis diversity and complexity

The second problem occurred after the power supply and network connectivity had resumed. Before the earthquake, Japan had developed a National Disaster Victims Support System in anticipation of major disasters. However, this system could not meet the diverse demands from the field because the actual requirements were different from those anticipated. The planned system failed. The field research of 13 municipalities revealed that a uniform plan across all municipalities would not have been appropriate because the situations in different towns and cities and the requirements for dealing with the disaster were continually changing. Both the extent and the scale of the earthquake damage were diverse, as the damage was due to combinations of quake and tsunami impacts. The affected areas were also very large with different geographical conditions.

In general, the local disaster management plans drawn up by each municipality specify the scope of action to be taken by the relevant organization during a disaster, such as setting up disaster response headquarters and confirming the safety of residents. Some plans also clarify the role of each operational division in the event of a disaster.

After the disaster response headquarters had been started up, many of the municipalities dispatched personnel for tasks such as operating evacuation centers and transporting goods under instructions from those headquarters. Further, although several of the regional disaster response plans stipulated that the role of ICT divisions during a disaster would be information services for the residents, this was not possible because key communication means were disrupted.

The response to support disaster relief operations is summarized below require a large number of people working at the disaster site to carry out numerous activities, including creating lists of survivor names and other information, manning resident service counters to issue Disaster Victim Certificates to qualify for disaster relief and other support systems, distributing relief money, accepting applications for temporary housing, and tearing down damaged buildings and clearing debris. Municipal governments are mandated by law to perform these tasks. ICT supports this role.

The disaster response measures taken by the ICT divisions of 13 municipalities surveyed can be primarily divided into the following:

1) Documenting evacuee names and other information (on paper and computer)

2) Restoring operation of information processing systems:

-Upgrade of existing systems

-Development and introduction of new systems

3) Verifying information in various lists with previously documented resident information

4) Issuing of Disaster Victim Certificates

Documenting personal information is an extremely labor-intensive task and though most of the municipalities made significant efforts to complete this unexpected post-disaster duty.

Uselessness of Planned Solutions

The National Disaster Victims Support System is a Linux based, comprehensive post-disaster support system endorsed by the National Government. It was developed in Nishinomiya City after the 1995 Hanshin Awaji Earthquake, which killed thousands, to prepare for future similar events. It consists of seven sub-systems, each of which is related to relief operations, such as opening evacuation centers; recording victims and their families; visualization of the status of damage on the map; and management of temporary residents; disaster relief goods; destroyed housing, and people who need support. All sub-systems are based on resident information and links to other government functions. Source code for the software was made openly available to other municipal governments in 2005 and to everyone including private companies after the Great East Japan Earthquake.

In spite of its good intentions and the investment, the system was not utilized as expected in the relief efforts. Although none of the municipalities had installed the system before the Great East Japan Earthquake, Miyako, Ishinomaki, Kesennuma, Minamisanriku, and Iwaki have introduced it since then. Miyako utilizes the system to manage the distribution of relief funds; Ishinomaki for the issue of Disaster Victim Certificates; Kesennuma for the management of debris removal; and Minamisanriku to manage distribution of relief funds and occupancy of temporary housing facilities. However, some of these municipalities had to modify the original software to suit local requirements.

On the other hand, following the disaster, eight other municipalities considered the introduction of the National Disaster Victims Support System, but they were forced to defer it for the following reasons:

- There was insufficient time to learn how to operate the software in a disaster situation;
- Installation on data servers was not successful;
- Data incompatibility required cumbersome conversion;
- A drop in performance was experienced when handling large volumes of data;

- Study and modification to the system could not be completed in time;

- There were operational differences with the developer (Nishinomiya City) regarding the format of the Disaster Victim Certificate and other issues.

In hindsight, all of the municipal governments affected had to conduct ICT development work at a time when people were starving and freezing. All of the problems mentioned could have been avoided if preparations had been made during normal times to configure the system and train personnel to be able to upload resident information immediately in the event of a disaster. However, even if these problems had been solved in advance, it would have been impossible to predict all the emerging demands because the field situation was changing continuously.

Municipal governments that abandoned the National Disaster Victim Support System opted to use simpler measures, such as spreadsheets. There were multiple instances of fortuitous IS development amid the crisis situation revealed by the interview (Table 6).

Table 6: System development of 13 municipal governments (Sakurai et al. 2013)

Municipalities interviewed		Example of new developments	Date
Iwate Prefecture	*Miyako City*	Modified the National system Developed original victim support system	Mid-May Late December
	Rikuzentakata Town	Developed original system for checking resident safety using open source software	Mid-March
	Kamaishi City	Developed original victim support system	Mid-April
	Otsuchi Town	Developed original victim support system	around May
Miyagi Prefecture	*Sendai City*	Modified existing tax collection system to develop victim support system	Early May
	Ishinomaki City	Modified the National system	Early May

	Kesennuma City	Developed original victim support system with Microsoft Access	Mid-April
	Higashimatsushima City	Developed original victim support system	Mid-April
	Minamisanriku Town	-	-
Fukushima Prefecture	*Iwaki City*	Developed original victim support system	Late May
	Minamisoma City	Developed original system for checking resident safety with Microsoft Access Developed original victim support system	March April
	Futaba Town	Developed original system for checking resident safety with Microsoft Excel	March
	Namie Town	Developed original system for checking resident safety with Microsoft Excel Developed original victim support system	March Late March

Open source software, Microsoft Access, and Excel were apparently widely used, as they were immediately available resources. Office staff members were already accustomed to these applications in their daily life and had less trouble customizing them for their purposes. It seems clear that information systems not used in daily life are not useful in an emergency situation.

New system developments in Tagajo City

The earthquake heavily damaged Tagajo, which opened a support center for disaster victims on April 1, 2011. Its primary tasks were to identify residents' whereabouts, acquire contact information (address, phone number, etc.), and assess damage inflicted on homes and properties, as well as to provide adequate information on relief programs. The number of deaths attributed to the disaster stood at 188 in April 2012, and one third of the entire city had sunk under the tsunami. ICT challenges encountered in Tagajo City included (1) recovery of lost connectivity (Internet/telephony), (2) reinstallation of terminals and the local area network to support resident service counters, and (3) preparation of residential data and information systems to use in citizen interactions.

Tagajo lost power immediately after the earthquake and recovered it on March 14, three days later. Network connectivity was lost until March 17, as base stations were damaged. The city was isolated from the world during this period and unable to collect or deliver information.

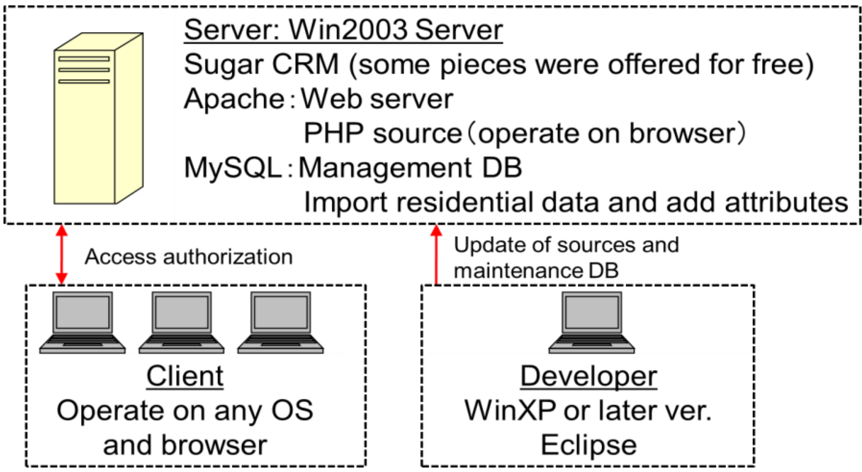
As two weeks had passed after the earthquake, the setting up of an information system became imperative, primarily to create records of residents' consultations. These data could then be linked to resident records, which would ensure consistency and continuity of support. Requirements for the system were (1) to serve each resident with consistent information based on the integrated records of all previously given instances of advice, (2) to have an integrated and simultaneously accessible database that could be accessed from multiple help desks, and (3) to remain available in the long term as most residents would likely need continuing assistance.

The city considered the National Disaster Victims Support System and investigated other solutions such as the Sahara System, which was developed after the 2004 Indian Ocean earthquake. These open source software solutions, however, could not meet Tagajo's requirements. Thus, the city decided to develop a new system.

It took Tagajo personnel only five days to create a system. Faced with a lack of resources, including time, the city relied on downloadable open source software. Necessary adjustments and additions were made to the software modules before integrating them to meet the mounting needs. Luckily, the server room inside the city government office was not damaged, and its hardware could be utilized to run the newly developed system.

A popular customer relationship management system in the commercial world, SugarCRM, was chosen as the core engine (Figure 4). SugarCRM could operate on common browsers and some pieces were offered free of charge. Thus, by limiting the use of the software to narrowly defined areas (records of advice, advisory officials, and advice provided), the city could freely customize the system for use.

Figure 4: Consultations record system developed by an official in Tagajo



Source: Tagajo City Office

Other tools utilized were PHP, MySQL, Apache server software, and the Eclipse development environment, all of which are available on the Internet. As the tools were open systems that required no more than browsers and came with little installation burden, existing equipment could be used. Access rights could be granted liberally as many of the tools were also license free, without the worry of having to pay for licensing or of violating copyright.

The system was developed to operate in a series of three steps:

1. Setting up resident identification. Data were imported from city governmental resident records to be used as the key for subsequently adding and searching records of advice.

2. Input of interview records such as residents' problems. Multiple resident visits produced new records on top of previous records under a single key.

3. Issuing consultancy records to advisees. To give a sense of assurance to residents, copies of interview records and advice were handed to persons at the end of consultations. Advisees could bring their copy to subsequent consultations.

The system was put into operation on April 1, 2011, in time to coincide with the opening of the support center. One hour of training was given to the advising officials who would operate the system. No major problems occurred, and minor functional additions were made as the system became operational. As of April 30, 2012, one year after the disaster, the system had supported over 30,000 consulting occasions with 700 officials, including officials who were sent by other municipalities as relief staff.

3-2-3: Lack of compatibility

After the newly developed system was operational in Tagajo, the integration of data across systems became a major issue. Various departments autonomously and independently developed several systems without coordination. This resulted in the lack of data compatibility among the systems (Table 7).

Table 7: Type of Disaster Relief Operation and New Systems in Tagajo City

Type of disaster relief operation	**Date of operation (2011)**	**Software used**	**Developed by**
Open disaster victim support center	April 1	Open Source Software	City Officer
Acceptance of temporary residences	April 1	Excel	City Officer
Issuing disaster victim certificates	April 20	Access	Pasco ltd
Temporary repairs of residences	April 25	Excel	City Officer
Management of contributions	End of April	Access	NEC Corporation

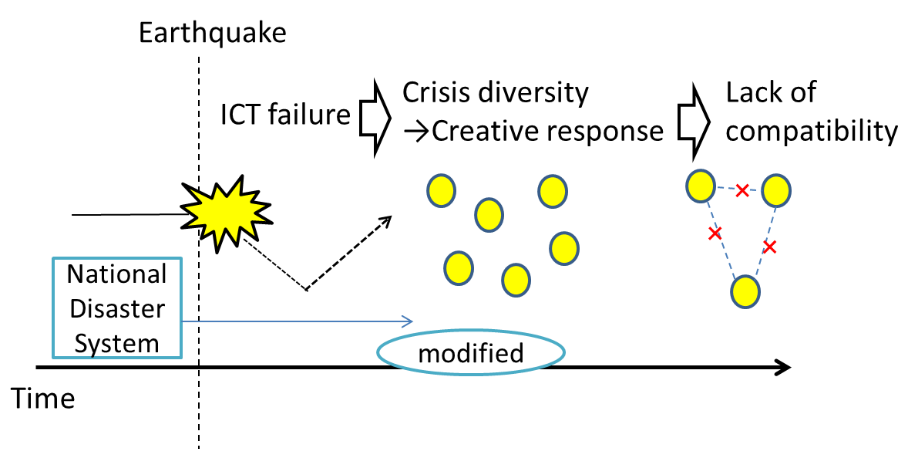
Source: Tagajo City Office

The problem was solved in the interim by using a conversion table and by resorting to burdensome manual operations. These conditions clearly illustrate the importance of preparedness for a creative response in the field.

Findings from the Tagajo City case study can be summarized as (1) recognition of the importance of a creative response following a catastrophe, and (2) availability of standard and open (as opposed to proprietary) systems which would enable a response without concern for fees and licenses.

In summary, there were three key IS problems after the Great East Japan Earthquake (Figure 5). First, the infrastructure failure lasted longer than anyone expected. Second was the diversity of the situations in the subsequent stage. This triggered new developments and modifications of existing systems, which we call a creative response, to take place. Local officers used whatever available resources were in the field. These creative responses met imperative needs; however, they occurred independently. Third problem, lack of compatibility occurred as a result of creative responses in the second stage. Yellow circles in the diagram represent a creative response, and it describes there were no connections (a red X in the diagram) between these responses.

Figure 5: Key IS problems



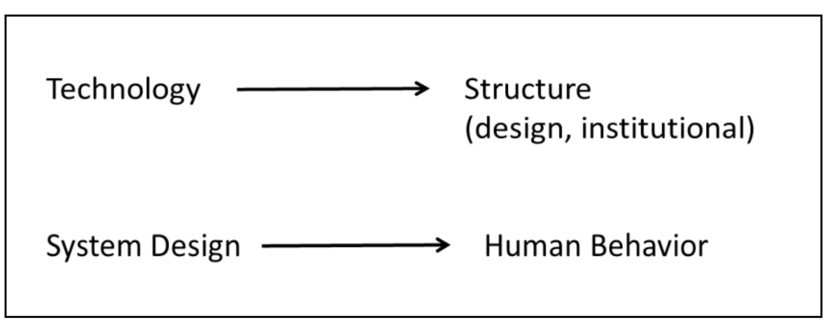
Chapter Four

Basic Thinking about Unexpected Events

What should we learn from experiences during the Great East Japan Earthquake? To understand the deeper structure of a phenomenon, it is important to explore reality more rigorously (Orlikowski et al. 1991). The literature helps us to understand what happened during the devastating disaster. A key notion from the literature is resilience, the measure of a system's persistence and the ability to absorb disturbances. In this chapter, basic thinking about responses to unexpected events and IS characteristics that we should employ to respond to such events are discussed.

Inadequate design, planning, and construction caused incorrect usage of systems and this leads to human behavioral problems (Benbasat et al. 2003). The design structure decides people's performance. On the other hand, design structure gets huge effects by technology, here technology means something to promote exploiting resources within organizations, which could be an independent variable when we set design structure as a dependent variable (Perrow 1983) (Figure 6).

Figure 6: Technology, Design structure, and Human behavior



Since the technology is developed according to society needs (Bijker et al. 1987), in other words, human action, the relationship between each item shown in figure 6 is supposed to become a circle, not only in one direction. This means, the notion of technology is recursive (Orlikowski 1992). "The structurational model of technology" termed by Orlikowski (1992) states that technology only comes from creative human action, at the same time, it becomes the mean of human action and has possibilities to change institutional structure. In terms of the relationship between technology and an unexpected situation, conventional discussion on dependability has assumed that the following four components is useful to realize dependable computing (Laprie 1995).

(1) fault-avoidance: how to prevent faults

(2) fault-tolerance: how to ensure continuity of a service in the presence of faults

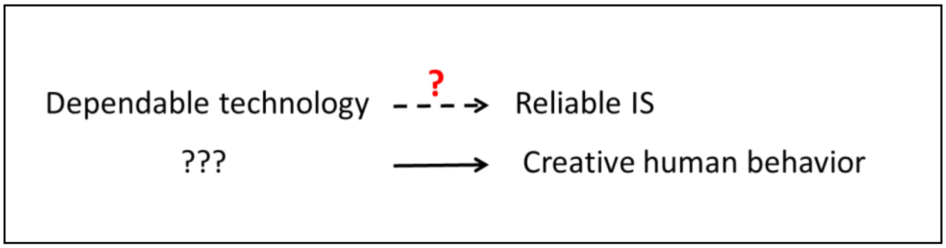
(3) error-removal: how to minimize of faults

(4) error-forecasting: how to estimate the future consequences of faults

In a similar approach, discussions in contemporary IS research appear to be mainly based on the idea that IS reliability is achieved through the use of dependable technology (Butler et al. 2006). Assuming reliability, the effectiveness of systems and processing capacity is given much attention. This focus, however fails to account for the infrastructure needs for IS operations in unexpected and overpowering situations.

During the Great East Japan Earthquake, no one had predicted that power supply and network connectivity would be lost for such long periods. This outcome made it clear to us that achieving perfect reliability is improbable. Here, an important question is which features of a system can improve capability that leads human behavior to be creative (Figure 7).

Figure 7: Dependable and reliable IS, and creative human behavior



Information technology creates an information environment, which enables flexible operations by utilizing knowledge in the field (Orlikowski 1991). While IS can ensure information quality and support decision-making in customary large-scale event management, there is a lack of research into what kind of systems would be useful in the event of a major disabling disaster (Chen et al. 2007; Ng et al. 2012; Reddy et al. 2009). We need to find an answer to the question.

4-1: Preparedness for unexpected events

Conventional disaster management plan intentions are to make people, facilities and organizations robust. This approach basically follows discussions of dependable computing. However, we learned from the Great East Japan Earthquake that robust systems work only in simulated situations. We need a new direction of thinking on responses when we face unexpected events. From the discussion of strategies (Mintzberg et al. 1985), the purpose of a disaster management plan should allow for an adaptable situation that recognizes new opportunities to formulate an effective response. In other words, we should change the purpose of disaster management to prepare an organization to think creatively about the unthinkable so that the best possible decisions will be made in time of disaster (Pearson et al. 1993).

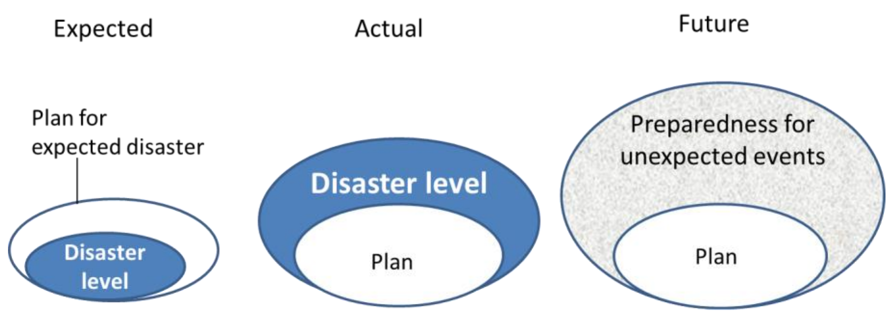
The plans defined the chain of command and the tasks to be performed (Gebbie et al. 2002). The field research reveals that the extent and diversity of damage can go far beyond any prior assumptions. This implies that even if BCP existed, a uniformly prepared set of responses would have been insufficient to meet the diverse and rapidly changing needs of the residents.

This by no means reduces the importance of planning. It is naturally useful to make predictions of damage and make plans to respond to the situation. Determination of the chain of command is critical, and it is wise to stock up on supplies based on a careful estimation of need. Such plans should also be widely shared by all people concerned.

At the same time, we recognize the importance of flexibility in decision making in executing disaster management plans (Kunreuther et al. 1985). To respond to changing situations, strategic incorporation of current information is essential.

For a future disaster planning and preparedness, we should establish the preconditions for responding to unexpected situations (Figure 8).

Figure 8: Preparedness for unexpected events



In this regard, preparedness is at the opposite end of "plans" that are made based on predicted damage. Damage within assumptions can be dealt with by plans. What we need, in addition, is to prepare for the extra capacity required for creative responses to damage at an unexpected level.

The question from the first chapter is which choices we should take, to avoid major failures by managing technologies or to maintain the capacity for facing unpredictable contingencies to adapt ourselves to unexpected situations. We learned that the attempt to avoid failures by managing technology settings in advance is impossible. Thus, our research led us to consider how we can create capacity for meeting unpredictable failures (Rochlin 1993; La Porte 1996). The key notion considered to create these capacities is resilience. Resilience identifies the capacity for collective action in the face of unexpected extreme evens that shatter infrastructure and disrupt normal operating conditions (Comfort et al. 2011), and the capacity of a community to mobilize action in response to threat, once it has occurred (Comfort et al. 2001).

4-2: The concept of Resilience

Discussion concerning resilience started with the examination of ecological systems (Bhamra et al. 2011). It begins by distinguishing resilience from stability (Holling 1973). That is, resilience is recognized as a measure of a system's persistence and the ability to absorb disturbances while maintaining the existing relationships between system entities. On the other hand, stability is defined as the ability of a system to return to an equilibrium state after a disturbance (Holling 1973). After that, the concept of resilience expands its scope to include the analysis of organizations (Horne et al. 1998), supply chain management (Lee 2004), engineering (Hollnagel et al. 2006) and business modeling (Gilbert et al. 2012).

4-2-1: Resilience or stability

The more resilience expands its scope, the more it gets diverse meanings. Engineering resilience is defined as how fast a variable returns to an equilibrium (Pimm 1991). Traditional systems engineering practices try to anticipate and resist disruptions but may be vulnerable to unforeseen factors (Fiksel 2003). This focus tends to try to conserve equilibrium, resist disturbance and change, and maintain its functions (Folke 2006). In a similar expression, supply chain resiliency is expressed as capability for recovering to its original state efficiently and effectively (Ponomarov et al. 2009). However, the core idea of resilience is, as the original notion by Holling says, to see disturbance as the opportunities for recombination of structures and processes, further, it provides adaptive capacity (Smit et al. 2006). In regard to this line, discussions in the business management field explain its resiliency well. To respond to market changes effectively, business models should take an organizational process that realizes a capabilities exchange without changing its mission (Gilbert et al. 2012). This exchange means to accomplish reposition and creation of innovative business source. Since the market environment is changing dramatically in recent times, a company's survival game increases its intensity. It is about continuously anticipating and adjusting to deep, secular trends and having the capacity to change the situation (Hamel et al. 2003). We can find this situation can be applied to public organizations, especially in a disaster occasion.

Resilience discussed in the context of emergency management has been incorporated into the international business process standard as ISO 22301 (formerly British BSI2599), which is intended to maintain business continuity at times of extraordinary stress. However, we now understand that municipalities' disaster relief operations are quite distinct from normal daily operations and only come into focus when a disaster happens. Disaster management demands more personnel to handle new problems that arise in the field (Post et al. 1986). Different types of demands and responses should emerge in such an environment, and it requires different levels of capacity in the system (Comfort et al. 2004). It is obvious that, before resources from outside the affected area are mobilized, municipalities have to deal with difficult disaster situations by themselves. In this phase, should we aim to just return to an equilibrium state or conserve the situation?

The notion of resilience provides adaptive capacity that allows for continuous development, like a dynamic adaptive interplay between sustaining and developing with change (Anderies et al. 2004; Berkes et al. 2003; Folke 2006; Zolli et al. 2012). Resilience thus involves identifying core missions that have to be performed under emergency situations, and applying whatever means available to achieve the key objectives. That is quite different from trying to create a robust system that can perform "as usual" under adverse conditions. The notion of robustness indicates to maintain system characteristics in spite of changes in its surrounding environment (Anderies et al. 2004), which is a similar definition of engineering resilience, and captures only one feature of resilience. What the aftermath of a disaster such as the Great East Japan Earthquake requires is indeed new capabilities to meet the situation.

Based on the literature review and the learnings from the Great East Japan Earthquake, resilience in this research is defined as *quickly gaining essential capabilities to perform critical post disaster missions and to smoothly return to fully stable operation thereafter*. Essential capability must be employed for conducting disaster relief operations. In regard to this line, our goal in emergency management should not be set as returning to an equilibrium state, rather, we should create a new environment to support gaining these capabilities in the field. Adaptive capability offered by a resilience framework sometimes effects ecosystems shape, when it faces uncertainness (Berkes et al. 2003; Gunderson 2001). Then, how can we create a new shape of environment? We move to the next topic to understand resilience more deeply. It seems to be valuable to look for an idea of resilience in an organizational field.

4-2-2: Organizational resilience

Horne (1998) identifies seven major streams of behavior within an organization which contribute to the development of resilience, such as (1) Community – understanding the people within the organization, (2) Competence – the fit between the capacity for blended skills to meet the demands of internal and external environments, (3) Connections – the relationships between persons, groups, and the system that determine the capacity and flexibility of the organization as a whole to respond under pressure, (4) Commitment – the ability of all sectors of the organization to work together during periods of uncertainty, (5) Communication – the information sharing, (6) Coordination – the timing of large and small change efforts throughout the entire organization, and (7) Consideration – the understanding by organizational leadership that change surrounds and interweaves into people's lives. These streams all relate to the ability to absorb change with a minimum of disruption. When we take an approach that sees organizations as "systems for getting work done for applying techniques to the problem of altering raw materials (Perrow 1967)," organizational resilience handles materials principles and relationship dynamics of complex ecosystems.

Materials refer to people, symbols or things. Research on organizational resilience explains how organizations achieve safety and reliability (Barton et al. 2009). This notion premises vulnerability of system structure.

Two approaches to achieve organizational resilience are suggested (Barton et al. 2009); they are, Normal accident theory and High reliable organizations (HRO) theory.

The latter High reliable organizations theory (La Porte 1996; La Porte et al. 1991) explains that organizations are supposed to employ abilities to prevent and to manage mishaps before they can spread throughout the system causing widespread damage or failure. They also have the flexibility and the capabilities to respond in real-time, reorganizing resources and actions to maintain functioning despite peripheral failures (Barton et al. 2009; Weick et al. 2001). Thus, HRO theory suggests that reliability and safety are achieved through human processes and relationships, rather than through changes to the system structure (Roberts et al. 1994).

The HRO theory sometimes appears in the term of "mindfulness." Mindfulness is defined as a rich awareness of discriminatory detail generated by organizational processes (Weick et al. 1999). Such mindful organizations spend (a) more time examining failure as a window on the health of the system, (b) more time resisting the urge to simplify assumptions about the world, (c) more time observing operations and their effects, (d) more time developing resilience to manage unexpected events, and (e) more time locating local expertise and creating a climate of deference to those experts. These capabilities have been labeled mindful organizing (Weick et al. 2001; Weick et al. 2006). If HROs do have accidents, it may be because they act with weakened mindfulness. That weakening occurs because they expend more effort to see things clearly (vividness) than to see one thing fully (stability) (Weick et al. 2006).

On the other hand, Normal accident theory (Perrow 1984) argues that even small failures that seem to have no capabilities to cause large accidents (according to Perrow, an accident is defined as an unintended and untoward event) perhaps would turn into major accidents because of unexpected interactions of failures. He warns that we usually forget the possibility of multiple small failures taking place at the same time. These failures are caused by system design, therefore the important thing to respond to in these accidents is to consider system characteristics. The key idea of system characteristics of Normal accident theory is "complexity." It is expressed as "tightly coupled systems", contrasting with "loosely coupled systems." Tightly coupled systems have only one way to achieve their production goals while loosely coupled systems allow multiple paths. For example, Perrow uses instances of a nuclear and oil plants, saying "A nuclear plant cannot produce electricity by shifting to oil or coal as a fuel; but oil plans can shift to coal." As a result, loosely coupled system can absorb failures because they can find redundancies and substitutions easily while tightly coupled systems should prepare these buffers in advance.

Connecting this discussion to the context of this paper, it suggests that the best approach to improving system reliability and safety is to change the system itself. Since this discussion is based on an assumption that the combination of interactive complexity and tight-coupling within a system will inevitably lead to failure and accidents, to reduce its complexity becomes an essential drive to realize resilience. This system should support flexible responses after functions fail.

The problems of systems' complexity

The case of Otsuchi Town located in Iwate prefecture, one of the hardest hit municipalities in the Great East Japan Earthquake, illustrates the importance of reducing systems' complexity when it requires recovery from the failure very well.

The town lost its mayor in the tsunami and his deputy's term was nearing its end on June 20, 2011. This forced the town to concentrate its efforts on implementing a mayoral election. Thus priority was placed on restoring the Basic Resident Registration Network System that would enable the town to generate a voter list.

The task was not easy. Otsuchi Town lost one-third of its employees when its three-story town office building was completely engulfed by the tsunami. The server room located on the first floor was submerged in muddy water,which disabled all the machines in the room. All data including backup was lost. As it was apparent that the old system could not be repaired, the decision was made to recreate the ICT environment from scratch in the server room of a temporary town office located in the grounds of Otsuchi elementary school.

The assumption had never been made that servers, robustly designed to withstand severe earthquakes, could actually be lost. Lack of preparation further complicated recovery. Most importantly, a security system to protect sensitive data on the servers blocked efforts to extract data from them.

This problem was solved by extracting residential data from a back-up database that was being fortuitously maintained by the town's system vendor. The data was then fed into a temporary system that the town had prepared in the community center near the temporary town office on March 29. The hardware was a server that the vendor was using for system development.

On April 13, restored residential records were fed into a second system also prepared in the community center to restart resident services including the issuance of residential certificates. The tax system and the residential record network system were also restored at this time. Naturally, the data was not current, but was rather that of March 11 when the tsunami hit.

Recovery of the Basic Resident Registration Network System, necessary to provide synchronized service in multiple locations, required the reconstruction of physical landline cables as well as of communication servers and firewalls. The temporary government building was too small to house these, so they were also placed at the community center. Server room construction and network connection was completed on June 15. Firewalls were installed on June 29. Preceding that, fiber optic cable was laid between the temporary town government building and community center building on May 20. An actual communications server was brought in on July 6 and went into operation after preparatory works on July 15. The town was finally ready to update its voter list by receiving data from other towns reporting people who moved out of town after the earthquake.

Heat became an issue by July at the town's temporary government building. Thus, all of the primary servers were moved to the community center where there was functional air-conditioning.

The mayoral election was carried out five months after the earthquake and two months after the deputy's term expiration, on August 28, 2011. Thus the town had been lacking a legitimate leader when leadership was critically needed.

On September 20, temporary servers were replaced by permanent servers that were placed in the server room located in the central community center. The only exception at the time was the vital records system that remained in the temporary government building. Finally, this system was also moved to the central community center. As of January 2012, all servers are permanently installed at the central community center server room.

Not all operations were restored as of January 2012. Unrecovered operations include the issuance of residential ID cards, a process that requires considerable installation work.

In summary, slow recovery of information systems caused a delay in the election process that, in turn, hindered all other recovery processes. It is obvious that slow recovery was caused by information systems complexity. The system was designed securely because it deals with residential information, which is supposed to be the most important and confidential data municipal governments have. Preparedness for elections is not usually included in a disaster relief operation; however, this case shows the harmful effects of complexity of systems. This illustrates the vulnerability of complex, hierarchically organized systems (Fiksel 2003) in an unexpected situation because they are resistant to stress only within narrow boundaries.

In this sense, organizational resilience based on the notion of the normal accident theory requires simplifying systems design.

4-3: Creative response in the field

Creative responses in the field were possible through open access to the resources and familiarity with the tools. New systems development in the 13 municipalities indicates the importance of promoting the collaboration of people using materials readily available at the time. As the case studies shows, organizations that are in charge of first responses such as municipal governments, fire departments, emergency medical services, and police departments are forced to meet urgent demands of disaster situations under time and resource limitation (Comfort et al. 2004). We need to design ICT that supports these responses in the field (Reddy et al. 2009). Accordingly, a creative response in this research is defined as *an autonomous reaction using available resources to gain the capability to meet key objectives*. Numerous cases related to creative responses in a disaster situation have been reported. For example, after Typhoon Haiyan in the Philippines in 2013, more than 900 people were lending a hand remotely by collaborating on online maps, through the OpenStreetMap network, which is open source mapping system and is available to every person on the Internet. It uses satellite technology and knowledge supplied by the public to help relief organizations, like the Red Cross, to know where buildings and roads are located and how and where to best deliver supplies.[3] During the Haiti Earthquake in 2010, a phenomenon called "voluntweeters" that supports information collection and transmission to disaster victims was observed (Starbird et al. 2011). IS enabled these kind of supports not only from outside of damaged area, but also from inside of the area. After a mountain fire in California in 2007, evacuees reconnected with their communities thanks to online neighborhood-based forums (Shklovski et al. 2008).

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3 Last accessed Apr. 29th 2014, at http://hereandnow.wbur.org/2013/11/15/mapping-effort-philippines

Information systems must have modifiability in addition to functional capability (to perform as intended) and responsive stability to conform to organizational requirements (Ashenhurst 1972). "Well functioning" systems may still have unsatisfied clients, this highlights the importance of citizen participation in systems development (Juergens 1977). In the context of this research, these calls for modifiability can be interpreted as calls for developing capacity among citizens to execute creative responses without external support reported above.

Juergens (1997) also mentions that stability and adaptability refer to future capability. Here, stability is the degree to which the capability of a system persists through changes in the system's non-user environment. On the other hand, adaptability is the degree to which adjustments to the system can be made as a result of changes in the user environment. An example is the ease with which changes in the information needs of the users can be incorporated into the system. Ability to allow this adaptability, rather than stability is required to a resilient IS.

What is at work here might be termed "bricolage," French for "tinkering," a notion advocated by Lévi-Strauss (1966) but more usefully defined by Weick (1993) in organizational management theory, where he applies it to improvised procedures with whatever materials are at hand. Chaotic situations normally disturb the fixed order of preconceived routine actions. At the same time, they restrict resourceful approaches in problem solving. Bricolage is seen to empower creative reactions under extensive pressure.

Technologies should support responding to particular task requirements with practical reasoning and empirical understanding (March et al. 1995). Conventionally, we believe that technology seeks to increase system performance. However, to develop the capability to adapt to new situations, we should consider the fact that people cannot easily accept new technology because it makes operators feel that the tasks they have to carry out are becoming more difficult as a result of it (Perrow 1983). The complexities of advanced technology as well as its heavy resource dependency are not desirable features of disaster response systems. Rather, the notion of bricolage, as attempting procedures with whatever materials are at hand, might become the means to offer adaptive capabilities, in other words, realize resilience. Bricolage produces something from what's available, by relying on people's capacity to improvise in the face of uncertainty (Baker et al. 2005).

We can find similar discussions in the field of creating new knowledge (Ciborra 1992). According to this discussion, there are two ways to create new knowledge. The first approach is to encourage tinkering to enable people to combine and apply tools they already have. In this method, local information and routine behavior are the key factor for tinkering but its arrangements or orders are random. The other one is an approach that restructures organizational backgrounds through learning. This aims to make innovation with mindfulness methodologies such as market analysis and system analysis etc., so that we can find similarity in HRO discussions.

In terms of system design, the following two approaches have been proposed (Banzhaf 2004): (1) a traditional design that contains complex principles and rules, and (2) an evolutionary design that contains a random combination of structural elements and follows simple design principles. Traditional design consists of the application of complex principles and rules. It is usually a top-down approach that begins with a high-level specification of the problem and moves down through a hierarchy of refinements until realization is reached. On the other hand, evolutionary design consists of an often random combination of a large number of structural elements. If not random, the combination follows simple principles. It is a bottom-up approach that often passes through a more or less complex developmental process.

4-4: How can we make systems resilient?

The question addressed in the beginning of this chapter is which features of a system can improve capability that leads human behavior to be creative during unexpected events. Firstly, the notion of resilience gives us suggestions on how to adapt to new situations. While the original definition of resilience by Holling (1973) recognize it as the measure of a system's persistence and the ability to absorb disturbances, this paper defines resilience in a disaster situation; it is to quickly gain essential capabilities to perform critical post disaster missions and to smoothly return to fully stable operation thereafter. Secondly, to gain essential capabilities, two approaches of organizational resilience are introduced; that are, Normal accident theory and High reliable organization theory. Normal accident theory insists that system's complexity allows few occasions for fortuitous substitutions and therefore it requires deliberate preparedness for its contingency, resulting be weakness in absorbing disturbances. High reliable organization theory has its focus on operational management and aims to develop a mindfulness organization. What we really want to explore here is how to create an environment to realize adaptive capabilities. In this sense, discussion of High reliable organization theory should not be on a par with Normal accident theory since the notion of normal accident theory has more of a systems perspective. Thirdly, the means for realizing resilient IS is a creative response in the field. This response promotes people to use whatever materials are at hand. The notion of bricolage, meaning improvised tinkering empowers creative reactions under strong pressure.

Evolutionary system design contains a random combination of entities and it is realized by a bottom-up approach. In this sense, IS should support various demands and promote random combinations in the field flexibly. This design encourages novel combinations formed by materials or insights (Weick 1993). As it is discussed in the first chapter, the effects of disaster management depend on mitigation and preparedness. Practically, mitigation aims to reduce vulnerability and preparedness aims to develop operational capability for disaster responses. These two stages, however, should be achieved together to generate creative human behavior in unexpected situations. That means the importance of creation of IS environments as a foundation for enabling random combination of entities available at the time of disasters to support creative responses in the field.

Part Two

Solution Design for the Future

“The only purpose for building an information system is to meet a human need, and only when we understand the deep structure of these needs will we build better systems.”

(Junglas et al. 2006)

Chapter Five

Requirements for Solution

In this part, discussions go into exploring how to realize resilience through IS design. A comparative study of the disaster-hit municipalities suggests that the concept of resilience is effective as a criterion for building a new disaster recovery strategy. However, it should be discussed at a practical level because existing frameworks do not provide operational steps for designing a resilient IS (Junglas et al. 2007).

As we discussed previously, IS implementation with an insufficient frame of system design causes social problems (Orlikowski et al. 1994). Design of systems involves the following steps: identifying system function and boundaries, establishing requirements, selecting appropriate technologies, developing a system design, evaluating anticipated performance, and devising a practical means for system deployment (Fiksel 2003). This paper focuses on leading design principles to support the initial response of municipalities that provide adaptive capabilities to its disaster relief operations.

To solve three key IS problems derived from case studies, a resilient IS design must ensure:

- Swift recovery after functions fail;
- A creative response;
- The integration of creative responses that occur independently.

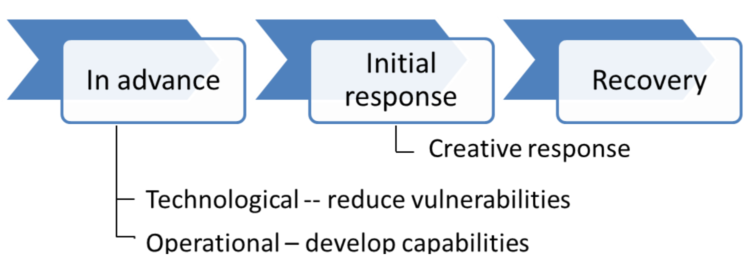
Our investigation strongly suggests that we need to depart from the conventional pursuit of system design to adopt a new disaster recovery strategy and IS design principle. IS research should contribute to provide necessary knowledge to this end.

5-1: Three stage model

To rigorously identify boundaries for the system that this research tries to design, I propose a three-stage model based on the chronological sequence necessary to deal with disaster situations (Figure 9). That is, “in advance stage,” “initial response stage” and “recovery stage.”

In the literature, emergency management has been categorized into four components such as mitigation, preparedness, response, and recovery (McLoughlin 1985; Settle 1985; Shoaf et al. 2000). Conventional emergency management research separates mitigation and preparedness, however, based on our observation and the literature review, we can see mitigation and preparedness as one and the same stage. Mitigation focuses on lessening the long-term risk, on the other hand preparedness indicates activities that develop operational capabilities for response (McLoughlin 1985). Then, how can we lessen the risk and develop operational capabilities in spite of difficulties in predicting what exactly will happen? This is the most important question for designing a resilient IS. Thus, I combine mitigation and preparedness into “in advance” to distinguish from the existing situation. Furthermore, we should divide technological and operational aspect through these three stages. In this sense, technological aspect aims to reduce vulnerabilities and operational aspect aims to develop adaptive capabilities. These should be implemented “in advance” of a disaster to support creative responses in the initial response stage.

Figure 9: Three stages for a Resilient IS



The British Cabinet Office, in its document entitled "Resilience in society: infrastructure, communities and businesses," defines resilience as anticipation, assessment, prevention, preparation, response and recovery from emergency situations.[4] The notion of resilience in a similar stage model categorized factors of resilience into 1) readiness and preparedness, 2) response and adaption, and 3) recovery or adjustment (Ponomarov et al. 2009). Proceeding from this theoretical basis, we clearly need to focus on "the in advance" preparedness for creative/autonomous response in any affected areas. To realize a smooth response immediately after a disaster, operational adaptive capability of officials should be created in advance. In terms of system requirements, there is a discussion that the most fundamental system requirement is redundant, fault-tolerant communications, and network infrastructure (Simmons et al. 2003), however, in this regard, technological aspect should place priority on reducing vulnerability with assumptions of systems failure.

In "the initial response stage," municipalities have to deal with the situation with very limited or no external support. Immediately after the disaster, municipalities need to conduct disaster relief operations with the limited access to resources. These initial operations are totally distinct from normal tasks and linked directly to saving lives. Thus, we need to design systems that recover quickly and allow creative and independent efforts in the field as well. The length of the initial response depends on the scale of a disaster. Prior research focuses on importance of the initial response because in this stage, resource and personnel should be strongly mobilized on their goals of saving lives, protecting property and meeting immediate demands (Comfort et al. 2011). In one case, it took 39 days after a disaster for outside help to arrive (Comfort et al. 2004). In our case studies, it took up to one month for effective IS related supports to arrive. During Hurricane Katrina in 2005 in the U.S., a local company named Northrop Grumman Corporation experienced unexpected disaster situation. An officer said, "The crisis team immediately recognized that the early stages of recovery were far more about restoring human resources than restoring information systems; nothing could be done

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4 https://www.gov.uk/resilience-in-society-infrastructure-communities-and-businesses, published February 20 2013

without personnel. Moreover, as systems were restored and normal business operations resumed, more and more time was required to handle the normal maintenance requests that were beginning to flow in (Junglas et al. 2007).” This illustrates the importance of officials themselves during the initial response stage. Municipal governments played a critical role, as they are the agencies closest to the residents. They have firsthand knowledge of the people and resources in their area, they are already at the disaster scene because they live there, and they are familiar with local customs and dialects. IS should support their creative responses immediately after a disaster.

As the initial response stage ends and outside resources are delivered to a disaster area, the situation settles down and stabilizes, though at a different equilibrium than pre-disaster. It gradually goes into a “recovery” process. Recovery consists of short-term activities that restore vital life-support systems to minimal operating standards and long-term activities that return life to normal (McLoughlin 1985). Then, it requires connections between emergency and normal systems. In this stage, self-organization, the spontaneous reallocation of energy and action to achieve a collective goal in a changing environment (Comfort 1994; Kauffman 1993), of creative responses emerges as a new design goal. If the number of creative response occurs independently as the case studies show, they luck compatibility, which hinders recovery. These various creative responses should be linked to avoid the friction of IS incompatibility.

5-2: Frugal IS

An IS is useful when there is a clear definition of requirements, and only when requirements are clearly defined can it provide an adequate solution (Beck et al. 2013). For a decade, the technology model has not been changed while information technology has changed greatly, becoming more complex, componentized, fragile, and its usage has become more diverse (Orlikowski et al. 2001). In terms of modeling information systems, an essential process is to define information needs (Bostrom et al. 1977). As the prior analysis shows, immediately following a disaster there is often a lack of communication capabilities and information processing resources. Then, what kind of requirements is needed to handle these situations? A notion of frugal IS, which is defined as “an information system that is developed and deployed with minimal resources to meet the preeminent goal of the client” (Watson et al. 2013) provides us fundamental information requirements that systems should employ. The frugal IS should focus on the dominant problems of the first few days of a disaster: determining the location and condition of the victims, helping them get emergency support, and identifying the missing. Such information is essential to managing the relief effort and informing concerned relatives and friends.

The four u-constructs (Junglas et al. 2006; Watson et al. 2002) are a basis for establishing frugal system design principles (Table 8). These four constructs represent information requirements. Here each of the drives is considered, starting with the universality construct because settling on a common communication platform is the foundation for satisfying the other u-constructs.

Table 8: Four information drives (Junglas et al. 2006)

Drive	**Definition**
Universality	The drive to overcome the friction of information systems’ incompatibilities
Ubiquity	The drive to access information unconstrained by time and space
Uniqueness	The drive to know precisely the characteristics and location of a person or entity
Unison	The drive for information consistency

To make explanation specific, the following section includes one example on using smartphones/cellphones that are considered to fulfill the above four constructs.

Universality

Universal usability, multi-functionality, and interoperability are key concepts of "universality (Junglas et al. 2006)." This refers to standards (Watson et al. 2013) and encourages using open systems that can be readily integrated. City officers in Tagajo used whatever available resources they could find in the chaotic situation. They combined multiple resources to develop the system. On the other hand, the most popular tools for new developments in the earthquake were Microsoft Excel and Access. The reason why municipalities used these applications is because they use them in normal tasks and are accustomed to them. Although these applications do not have multi-functional characteristics, the notion of universality should incorporate people's familiarity with the tools.

A smartphone is universal because the open API that today's smartphone usage allows many creative developers in the field to develop applications that meet local needs. Such universality also means that smartphones are multi-functional and can meet the various needs of individuals in everyday life and during disasters. In reality, during the Great East Japan Earthquake, a cellular phone was the most widely used communication tool because people were already familiar with it. Nowadays people use smartphones more than cellular phones.

A frugal IS must be compatible with existing systems that disaster victims are likely to possess and should require them to acquire minimal new technology, if any. Smartphones, which are advanced cellphones and becoming very common, are portable, battery powered, often within the owners' easy reach, incorporate a GPS, and have the capability to run apps. Because cellphone adoption is 96 percent globally, 128 percent in developed countries, and 89 percent in the developing world, respectively (Union 2013), it is one possibility to make the cellphone/smartphone the standard platform for a frugal emergency relief IS. To further enhance universality, all cellphones/smartphones should have a pre-installed emergency app that can be remotely updated as required. Such an app should be created and maintained by the appropriate national emergency agency. Language is a major form of friction between ISs. People in a disaster zone might well speak a different language than some relief workers. Thus, this dissertation envisages an emergency app that transmits a code (Table 9) as well as the GPS location and the sender's phone number. A code can readily be converted into the language of the receiver. A code is frugal in terms of bandwidth requirements. Similarly, there can be another set of frugal messages to support communication with victims.

Table 9: Universal message coding

Message	Code
I need water	1
I need food	2
I am injured and cannot move	3
:…	…

Smartphones require power, but most should have sufficient battery power to continue to operate for a day or so. In addition, a hand-powered phone battery charger should be added to the recommended household emergency kit. Municipalities should also establish an emergency phone charging resource because their relief workers are likely to use smartphones during the initial response stage.

Ubiquity

To secure ubiquitous information access, we need to develop network connectivity that enables quick recovery after functions fail. If ubiquitously available smartphones, standard PCs, and non-dedicated public Internet services can be used, the chances of creatively developing disaster relief systems with "whatever available" resources increase. This will empower stranded people to help themselves before outside helps arrive. Regarding network connectivity, in reality, after the earthquake, satellite Internet base stations and portable mobile phone base stations (cars) were sent to the damaged area. However, they arrived at the area a couple of weeks after the earthquake because of poor road conditions. During Hurricane Katrina in 2005, cell phones, Blackberries, and landlines gradually became useless. This made it difficult to collaborate among several organizations which were in charge of providing disaster relief supports (Comfort et al. 2006). Staying connected should be one of the main IS requirements for handling large events (Ng et al. 2012).

Victims and relief teams need ubiquitous access to essential information wherever they might be in the disaster zone. Because it is likely that essential infrastructure has been destroyed, there is a need to quickly deploy an alternative wireless communication system that is compatible with the victims' cellphones and can cover the relief area. A cellphone network must provide both coverage and bandwidth to service customers.

Uniqueness

Information that will likely be shared during disaster relief operations should employ the notion of "uniqueness." This means recording attributes (such as the profiles and location) of a person or entity. This is essential to identify objects. Time will frequently need to be recorded to uniquely identify events and track their relationships.

The identity, location, and condition of victims must be established as soon as possible. In addition, there is a need to identify locations that are hazardous (e.g., a radiation leak) or require a rescue team (e.g., a demolished building). Because the cellphone is typically a personal device, there is a one-to-one mapping of a cellphone number to a person. The full identifier, country code plus phone number, needs to be used to allow for visitors. What is often missing, as the disaster demonstrated, is a national or even local government-based, integrated database that records this mapping along with a person's home and work addresses and some minimal personal (e.g., birth date), family (e.g., details of children), and critical health (e.g., diabetic) data. Such information means that the general and unique needs of a disaster area can be quickly determined (e.g., the number of doses of insulin). While a disaster is often seen as a national tragedy, it is a combination of many individual calamities that frequently have unique needs.

Unison

"Unison" indicates the importance of consistency of data among different locations and databases. This would be the most essential factor to prevent the lack of data compatibility. This also enables people to share information with any devices at any time. On the other hand, it would become a significant defect at the same time when we try to adopt creative responses, usually undertaken by autonomous individuals or groups as a solution to meet the disaster relief mission.

Information about victims and where they live can be scattered across multiple databases (automated and manual within the community, in regions, and in national registries), and during an emergency there is often a need to integrate these data. Such integration, however, should be prepared prior to the need, as identified in the prior discussion on uniqueness. The tension between the general need for privacy and the specific needs of a disaster should be accommodated in line with existing or new national laws. Unison also comes into play in another way. Keeping details of victims is critical to managing the recovery. Each relief station needs to keep track of who is housed where, who is receiving assistance, and so forth. Relying on paper records can result in a lack of information consistency. Written names can be miskeyed, and databases then become unreliable. The recording process needs to be fast, efficient, and designed to maintain unison across recording events as victims move.

The cellphone is one possibility for maintaining unison because it is a person's electronic identifier. The emergency app needs a feature that transmits (e.g., Bluetooth or NFC) its phone number to a rescue worker's cellphone in the field or at a relief center. Each relief worker's list of phone numbers and coordinates could be uploaded automatically to a computer system. Creating single integrated database and ensuring consistent identification of entered data is fundamental to maintaining unison. In the case of an emergency, the key identifier is the phone number of the victim. The lessons from the Great East Japan Earthquake underscore the importance of unison, and this is perhaps the u-construct that should be pursued with the most vigor. However, without the other constructs in place, it is not feasible to have unison.

Chapter Six

Development of Design Principles

The recognition that extraordinary, special needs emerge in post disaster situations, resilience involves identifying essential missions that have to be performed under emergency situations, and applying whatever means is available to achieve the key objectives. This is quite different from trying to create a system that can perform in a stable situation under adverse conditions. Proceeding from this basis, we clearly need to focus on preparedness for creative response in any affected areas. So, we can apply this notion and frugal concept to the three-stage model (Table 10). Each stage should have different principles and strategies.

Table 10: Sequence of events (based on system design) and future design principles

	In advance	**Initial response**	**Recovery**
Expected	Robust system that continue existing IS and ICT as usual assumed level disaster Preparing back up resources for uninterrupted service	Continuing system operations as usual	
Actual		Extent and diversity of the damage far beyond any prior assumptions ICT failures lasted longer than expected Different operations require ICT resources	Creative response to deal with diversity Lack of coordination among the local efforts Data integration problems
Future	Adopting open and standard technologies	Using universal and familiar devices	Seamless transfer of data from creative solutions to normal

	Preparing ubiquitous tools and network connectivity	Keeping information uniqueness Using data from the ordinary system Using consistent codes to maintain unison	operations

With a better understanding of the post-disaster phases, can we have any "in advance" preparations to conduct initial response and recovery efficiently? Business continuity planning (BCP) plays a role in defining actions for all recovery processes uniformly. Many organizations will have BCPs (Cerullo et al. 2004). None of the 13 municipalities interviewed had a particular BCP, but all had local disaster management plans. The plans defined the chain of command and the tasks to be performed. However, unless plans can be intuitively applied during fast emerging crises, they will not be effective (Bhamra et al. 2011; Seville et al. 2006). Our field research reveals that the extent and diversity of damage can go far beyond any prior assumptions. This implies that even if a BCP existed, a uniformly prepared set of responses would have been insufficient to meet the diverse and rapidly changing needs of residents.

Before we can understand what needs to be done during the in advance stage, we need to look at the initial response and the recovery stage first.

6-1: Initial Response Stage

Although none of the 13 municipalities interviewed drew up BCP, according to a regular BCP guideline that was created by the national government, they assumed to continue existing IS and ICT as usual in case they would face a disaster. The Great East Japan Earthquake revealed the national government lacked the recognition that a disaster management operation of municipalities is essentially a different type of operation. As was mentioned previously, the top priority of public organizations in a disaster situation is to save lives and help its residents.

Initially, local officials need to operate without support from outside of the damaged area. As the case studies show, since no one had assumed that power and network connectivity failures would last for such a long time, municipalities damaged by the earthquake could not respond effectively. To make the initial response effective, Japan had prepared a National Disaster Victims Support System; however, it was developed almost 20 years ago and could not meet various demands from the field. Although it had employed an open source policy, i.e., there was room and freedom to make adjustments; it was nevertheless sufficiently efficient to allow staff in the field to develop new applications flexibly in response to the new reality. The National System was a closed system in the sense that it required installation prior to disasters with access keys distributed by the national government. It also lacked compatibility with other widely available systems.

In this stage, quickly gaining essential capabilities to perform critical post disaster missions is necessary to realize resilience. Municipal governments' operational goals in the initial response stage are to confirm the whereabouts and safety of residents, open evacuation centers (and create evacuee lists), and transport relief goods to them. Functional requirements to realize these operational goals are the identification of persons (individuals) and goods and the compilation of a disaster victim database. In addition, information sharing capability among persons who are involved in a disaster relief operation is essential. Because of the unexpected ICT failure, these operations basically were conducted with analog methods. It demanded labor-intensive tasks and therefore, delayed the recovery process.

The important thing is to enable people in the field to operate the above operations creatively. One means for supporting creative responses is "bricolage" that produces something from what's available, by relying on people's capacity to improvise in the face of uncertainty (Baker et al. 2005). Bricolage indicates the same direction as the notion of evolutionary system design (Banzhaf 2004), which refers to ability to create random combination of entities. This style of design is realized through bottom-up approach, in other words, from the field.

It is necessary to use universally available and versatile devices that encourage using open systems, which makes it easier to integrate entities and to support bricolage in the field. In addition, these devices should be those that people already have and with which they are familiar in order to promote smooth response in the initial stage.

Data that are collected during the initial response should be dynamic. These data must employ uniqueness to identify people or entities by their characteristics, location, and time. This would make it easier to understand a situation and to connect with information collected by other sites. For example, think about a case where there are four Mr. Katos in the same evacuation center. Without uniqueness, there will be confusion as to which Mr. Kato requires a specific medication or which one needs hospital treatment. At the same time, we should use consistent codes to maintain unison of data.

Consequently, these design principles assure minimal resources.

6-2: Recovery Stage

The initial response gradually becomes a recovery as efficient support for disaster relief arrives in an area. In our case studies, after the ICT infrastructure had been restored, creative responses were observed in several locations. However, a lack of coordination among the local efforts caused the subsequent lack of data compatibility. This led to loss of efficiency in the later stages of disaster relief. Recognition of the seriousness of the data incompatibility leads to the conclusion that there needs to be more research on the relationship between a creative response and self-organization.

Self-organization is defined as “new forms, structures, procedures, hierarchies, and understanding emerge, giving a new form to the system, often at a higher level of order and complexity (Procopio et al. 2007).” Self-organization has characteristics such as adaptive and scalable interactions between the entities. It also is localized and has no central coordination (Prehofer et al. 2005). To enable each creative response to be scalable and adaptive, the notion of unison is essential. In addition, as municipalities return to normal operations, a creative response needs to share information with IS that are used for standard operational tasks. Unison means information sharing between temporary systems and standard operational systems. Even as municipalities returned to normal operations, operations such as providing relief programs to disaster victims continued. In some cases, they lasted several years. In Tagajo, for example, disaster relief programs were still being delivered to its residents as of July 2014. The city no longer used the temporary system developed during the crisis and had returned to the conventional system. Ironically, this led to the loss of data compatibility among systems of the various departments involved in the relief effort. The lack of compatibility can limit the ability, for example, to detect fraudulent multiple relief claims.

As municipalities' disaster relief operations are quite distinct from normal day-to-day tasks, the requirements for information systems become different as well. It should recover quickly and support a creative response in the field. It is thus natural to return to the conventional systems designed for normal use. However, the experiences of the earthquake indicates the importance of (1) a seamless transfer of the recording of each resident's situation with unison from temporary systems to the normal use systems, as well as (2) data compatibility among systems for normal operations.

In this stage, the characteristic of resilience becomes different. It focuses on the degree *of smoothly returning to fully stable operations.* This means that we should measure the degree of data compatibility among temporary systems and normal ones.

6-3: In Advance Stage

While this paper emphasizes the role and importance of a creative response to deal with unexpected events, it does not assert that preparation is meaningless. Rather, it emphasizes the importance of adopting open and standard technologies for our peacetime systems so that data from the system can be extracted and used by creatively developed systems in the field.

Before the Great East Japan Earthquake, a BCP guideline had only recognition of continuing ordinary systems. After the Great East Japan Earthquake, the national government drew up a new guideline for BCP that focuses on municipal responses immediately after a disaster. It sets out to show how to prepare disaster-proof technology to support disaster relief operations. It includes preparedness of substitute resources such as emergency power generator to continue systems' operation after a disaster. This focuses much on reducing vulnerability, however, it misses explaining how to respond to unpredictable disasters, in other words, how to develop adaptive capabilities that strongly affects the initial response stage.

During the Great East Japan Earthquake, each evacuation center created separate and unstandardized evacuation lists that were not based on the official residential database. This made the job of later stages of data integration very difficult. This data fragmentation problem informs us of the importance and the challenge of maintaining data unison in a disaster setting. This is a critical element if we want to see multiple creative responses self-organize to become mutually reinforcing parts of a large collaborative effort. It will make the transition from initial response to longer-term recovery smoother.

In the in advance stage, preparation of unison databases is essential. Databases should include static characteristics, such as residents' medical information and household membership details. In a previous example, the static characteristics of Mr. Kato would be gender, date of birth, address, phone numbers, medical prescriptions, and family situation (whether he needs special help in the disaster or not). These data should be linked in the database that would be used in the initial response stage. This helps in maintaining unison and uniqueness of information when data from multiple systems are merged in later stages of disaster recovery.

In addition to this, development of ubiquitous networks is critically important. These days, we can assume network connectivity everywhere. We can also assume that most people own universal devices, such as smartphones, which are able to connect to the network easily. As long as ubiquitous connectivity is sustained, personal device, provided they have sufficient charge, are available during a disaster. To support the in advance stage, applications might be designed to run in environments and on devices that can support the four u-constructs (e.g., an app running of a smartphone with access to a database).

We need to make sure such devices become operational and widely used before they are needed and then made available as quickly as possible after disasters. With regard to preparedness at a practical level, FEMA (The Federal Emergency Management Agency) is adopting a five category exercise model, i.e., orientation, drill, tabletop, functional, and full-scale (Watkins 2000). Normally a fire drill is conducted once a year in each municipality, but it focuses on how to escape to an evacuee center and does not emphasize how to support officials and residents with using ICT. We should recognize the importance of running a fire drill based on an information systems failure. This means that we turn the power off for the information systems and start from the initial response stage assumption.

6-4: Applying the proposed Frugal IS to the Great East Japan disaster

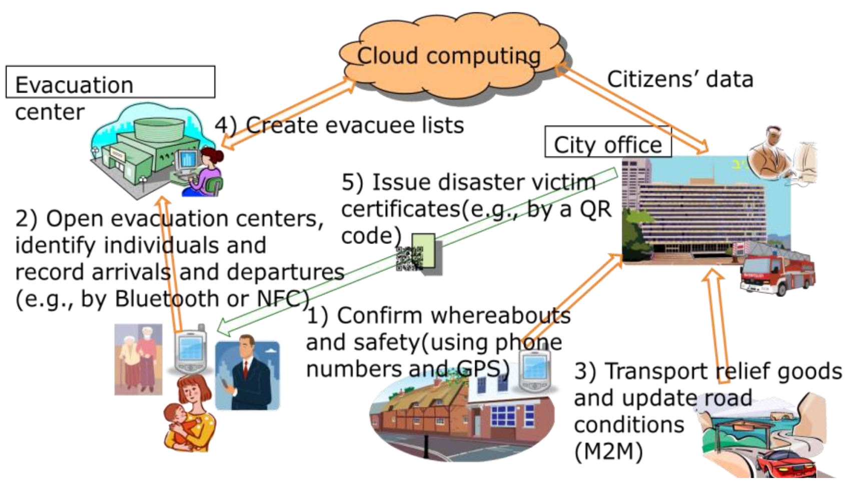
Looking into the future, a smartphone will be the tool that meets the frugal design requirements better than any other device. Firstly, it can be kept live easily by a manually cranked charger. Secondly, a smartphone can be connected either by cellular network or Wi-Fi networks if the cellular network is down. Wi-Fi is probably the most frugal and ubiquitous connectivity tool around presently and thus is likely to be the most resilient. Thirdly, it also employs the notion of “uniqueness” and “unison” because each carries a unique phone number and SIM card. By associating the information of individuals collected with number of a personal smartphones, the uniqueness of the individuals is maintained. It will also be easy to link information of a same individuals collected in various locations.

Here is one scenario applying previous discussion to handling disaster relief operations. This is just one possibility to realize frugal IS foundation but is not perfect answer. However, the Internet connectivity compatibility of contemporary smartphones and their widespread adoption makes them the most likely candidate technology for fulfilling the four u-constructs. While hindsight is not the best method of testing a design, it is the best alternative at this point.

Consequently, the design by examining the performance of five primary operations of municipalities during the disaster is shown in Figure 10.

This proposal focuses one possibility on recovery of cell sites, based on our observation that they recovered much faster than other components of the telecommunications infrastructure, such as the WAN that connected municipal government offices.

Figure 10: Frugal design in disaster relief operations



Confirming the whereabouts and safety of residents

From the municipal governments' perspective, confirming the whereabouts and safety of residents requires (1) recognition of the surviving resident, and (2) communication of information to the outside world.

As for the recognition of the surviving residents, if the cell system is operational, residents can send identifying messages from their cellphones. If the system is not operational, identification can be achieved by registration of residents' IDs at evacuation centers or other facilities set up by the municipal government. This can be accomplished by setting up a local communication link between cellphones.

There is a possibility that municipal governments collect residents' cellphone numbers as well as GPS generated location information in addition to conventional name, address, gender, and birthdate. This will help to maintain the uniqueness of identification and database unison. Thus, preparation for integration of official residential data and carrier user data will be essential, but it will likely require authorizing legislation in many countries. The collaboration of citizens with the public sector is thus an important element in applying frugal systems thinking in disaster readiness planning.

We need to consider the case of people who do not have a cellphone with them or do not own one (e.g., children). Those in the first category should be able to remember their phone number and this can be manually captured. The second category can be identified by adding a digit to the phone number (e.g., +1 999-999-999-1 for the eldest child). To prepare for those who neither have a phone number, cellphone equipped relative nor guardian (e.g., a solitary elderly), we could allocate a set of unused numbers to evacuation centers in advance for identifying such people.

As for the communications to the outside world, the ideal situation is to have cell sites back in operation quickly. If this is not accomplished, we need to consider alternatives to rapidly create a low bandwidth ubiquitous communications network. Alternative means of connectivity will be discussed in next chapter.

Establishing and operating evacuation centers

Once a municipality has physically established evacuation centers, it needs a frugal IS to record data about who arrives at or leaves a center. Again, the universal nature of the cellphone means it becomes a key device for exchanging essential data between survivors' and relief workers' cellphones. An advantage of this approach is that it allows off-line local processing when the network to the outside world is not operational. Stored data can be transmitted to the integrated database as cell sites become operational. Local centers should be able to draw on this database using a preset small number of queries that require minimal ICT resources.

As power and communication systems are established, there must be a smooth migration to computer-based, rather than phone-based, information systems.

Transport and management of relief goods

In the Great East Japan Earthquake recovery process, a lack of information caused a massive mismatch between the supply and demand of relief goods. Not only there were shortages, but there were also instances where relief goods were delivered but rotted because the demand was already met. Perhaps the accuracy requirement is lower than for survivor identification, but it is critical to have unison and uniqueness in the identification of the needs and supply of relief goods.

A cellphone-based system would help to more closely match the local needs with supply capabilities. Requests accompanied by the ID of phones that dispatched the request and location data would be useful in tracking how demand is being filled. If the receipt of goods could be registered by the same cellphone, redundant supply should be reduced and diverted to where needed.

The same applies to transportation resources. For example, as disruption of the road system is likely, those delivering supplies need a separate frugal IS to be able to report failures in the road network and get advice on new routes. The same u-constructs can guide design of this system. We imagine a system where a copy of the existing road network is dynamically updated with the latest availability data and used to create dynamically new routes.

Cellphone-based systems can be used to report usability of road systems from the ground up. We can use of such citizen-generated information (CGI) will be of critical importance in the design of future communities.

Support of evacuees and creating evacuee lists

The power of a GPS enabled cellphone-based system is that the data on citizen's whereabouts and condition can be collected in the field as well as at evacuation centers with stand-alone processing. Thus, rescue teams might well include a data officer, carrying a high capacity battery, who can identify each evacuee's needs before they reach a relief center so the center has time to gain some advance warning of the types of support required. In an emergency, a few minutes extra can be lifesaving.

The actions taken to confirm the whereabouts of citizens become the foundation of evacuee lists. Once a disaster happens, inquiries about confirming the whereabouts and safety of residents from outside of the area concentrate on municipalities. Since people in evacuation centers moves to other centers all the time, real-time tracking people's arrivals and departures becomes essential. As these lists would be transmitted to the cloud as soon as bandwidth was available, they could be made generally available, with appropriate privacy safeguards, to inform relatives.

Compilation of the victim database is a sensitive operation. One should expect, and try to meet, the many inquiries from the outside world desperately wanting information about relatives and friends. At the same time, we should be aware of the privacy concerns with such a database. The Japanese privacy law exempts databases for disaster relief from its regulations. At the same time, ambiguity surrounding the law forced each municipal government to exercise its judgment and prevented them from taking unified action. As a result, one city publicized an evacuee (survivor) list on its home page while a neighboring city would not even answer telephone inquiries. There is a critical need for a unified guideline to prevent such fragmented actions.

Cloud computing could be an effective infrastructure to house a critical database (Pokharel et al. 2010). It would be particularly useful in integrating the numerous databases that might be compiled in evacuation centers. Municipal governments are already taking action to adopt a public cloud to share costs. However, as cloud computing assumes connectivity, its reliability would likely be compromised because of infrastructure damage immediately following a large-scale disaster. Thus a more local solution is required for situations immediately after a disaster. Data created by the local solutions should be transferred to cloud systems when connections are restored.

Issuing of disaster victim certificates

The proposed frugal IS captures essential data about each victim and tracks movement between evacuee centers. In effect, it creates an audit trail that can be used to distinguish the genuine victim from the fake. Once a person's right to a certificate has been verified, this could be issued electronically (e.g., send a QR code to their cellphone) as well as being recorded in the database for subsequent reference. The issuing of victim certificates illustrates the power of frugal thinking. We can use what the victim is very likely to already have and avoid additional resources (e.g., printers).

Of course, there needs to be a workaround for those who do not have a phone, and in this case a possible frugal solution could be based on small printers that can generate a paper-based QR code.

Chapter Seven

Evaluation of Generalizability and Contingencies

After the development of implications from case studies, replicating its theory becomes important (Yin 2008). Since this research is based on the interviews from the Great East Japan Earthquake, the external validity of the findings is limited. Here the question is, how much can the design principles be generalized?

In this chapter, three primary variables that are likely to affect the generalizability of the frugality framework are considered. The first variable is network connectivity. Since this paper argues the importance of building ubiquitous access to information, there might be limits to the applicability of frugality. Although the scenario shown in the previous chapter is useless without quick recovery of connectivity, connection to the outside world requires large-scale systems that are costly while the connectivity within communities will have to depend on bricolage. The second variable is disaster types. Natural disaster refers not only earthquake but includes other types of disaster, represented by flooding. I try to apply the resilience theoretical framework to the analyses of other types of disasters in Japan that frequently suffer from catastrophes. The survey result on communication channels used by municipalities during other types of disasters such as heavy rain will be shown.

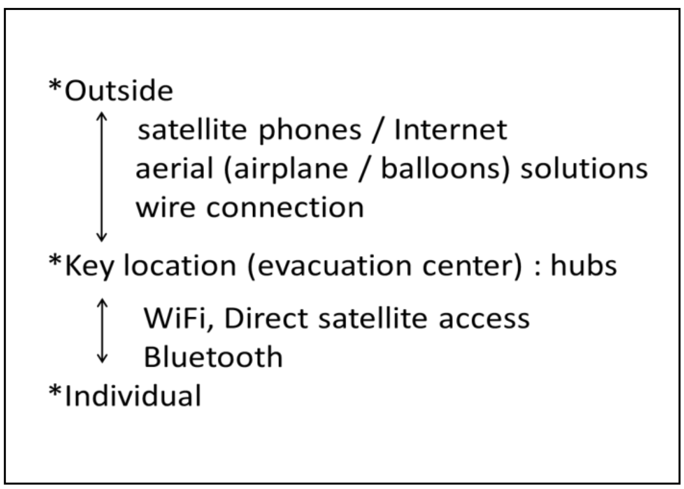
The third variable is the reality of using citizens' own device in disaster relief operations. While the frugal approach endorses "the use of whatever available" and "tools for daily lives," that requires integration of systems that are under control of diverse range of people. We need to consider the reality of such an approach. With this question in mind, I conducted a field test to verify the notion with a large system integration company in Tome City in the fall of 2014.

7-1: Technical options for connectivity

While we observed the relative robustness of the cellphone network compared with terrestrial networks during the Great East Japan Earthquake, we should nevertheless assume that the network will fail and consider alternatives.

Assuming local cell sites are not operational, we need to think about (1) connectivity between local hubs (e.g., evacuation centers and city offices) and outside and, (2) connectivity between the hub and the individuals' devices (e.g., cellphones) (Figure 11).

Figure 11: Emergency network connectivity



7-1-1: Connectivity to outside

First, likely options for connectivity between hubs and outside include a) satellite phone/Internet services, b) aerial (airplane/balloons) solutions, and c) wired connection. The problem is, these options are costly and we cannot say it is a frugal solution, which aims to develop systems with minimal resources.

Satellite Internet services (we distinguish IP-only satellite Internet services from conventional voice-centric satellite phone services) will be a most realistic candidate, at least for the time being, albeit with limited capacity. In the case of the Great East Japan Earthquake, "ICT Supporter" operations organized by the Japan Electronic and Information Technology Association (JEITA) started to restore information systems one month after the disaster (Team 2011). In the three months of its operation, 95 requests/operations for relief were conducted. While the primary effort was directed at delivery of equipment, connectivity support, such as satellite Internet access, was provided in the most severely hit areas along the coast. In those areas, the trunk cable among cell sites was hit so hard that it was not realistic to restore the system. Instead, portable satellite Internet earth stations were brought in to enable connectivity to isolated locations and individual devices were connected using Wi-Fi. Satellite Internet earth stations can be purchased for less than USD 3,000 per unit with running costs of USD 50 per month (1Mbps/512Kbps) (Communications 2011). It is a realistic way to restore connectivity and faster than trying to restore trunk lines among mobile phone cell sites (Kataoka et al. 2009). However, is this we assess, an affordable price for many facilities to install for daily use?

Another possibility is the Iridium (satellite phone) commercial service for which handheld devices are a little more than USD 2,000. While this is comparable to satellite Internet services, there is a major difference in that the usage charge is more than USD 1.5 per minute (in addition to a base charge of about USD 50). This means local communities are unlikely to regularly use this technology, which we consider to be a critical factor in evaluating a technology's usefulness immediately following a disaster. In a crisis situation, unfamiliar technology is an impediment to action.

Specifications for spatial connectivity for the aerial cell site will depend on the type of communication device deployed, such as an aircraft or balloons launched for ground coverage.

For example, the E-3 Sentry US Airborne Warning and Control System (AWACS) can provide up to 320 km of coverage to facilitate ground to air communications.[5]

Alternatively, Google's "Project Loon" proposes floating balloons 18-27 km above the earth's surface to cover an area 40 km in diameter to enable connection of hundreds of cells at speeds comparable to 3G.[6] Such balloons offer a faster connection than currently available via satellite Internet. A box of electronics is carried by the balloon and contains GPS, sensors, Internet antennas, and 100 watts of solar power, which runs the electronics and keeps an on-board battery charged for four hours of use at night.[7] The balloons are designed to stay aloft for 100+ days. Additionally, "for balloon-to-balloon and balloon-to-ground communications, the balloons use antennas equipped with specialized radio frequency technology. Project Loon currently uses ISM bands (specifically 2.4 and 5.8 GHz bands) that are available for anyone to use." [8] The system can be equipped with ISM/GSM Cellular RF antennas, which can provide Wi-Fi capability. As this technology is in the experimental phase, it is currently difficult to determine costs. It would have required about 12 balloons to cover the long rupture zone areas of the Great East Japan Earthquake.

Similar prototypes have been tested for ad hoc communication systems at lower and more controlled implementations. For example, SKYMESH, an urgent communications network backbone, supports balloons 50-100 m above the ground. It takes advantage of good line-of-sight, low interference, and long transmission range for collecting disaster area

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5 Last accessed 17rd Aug, 2013, at http://www.fas.org/man/dod-101/sys/ac/e-3.htm

6 "Google Project Loon, Balloon-Powered Internet for Everyone", last accessed 17rd Aug, 2013, at http://www.google.com/loon/

7 Last accessed 17rd Aug, 2013, at http://www.greenbiz.com/news/2013/06/22/google-harnesses-wind-solar-spread-internet-everywhere-balloons?mkt_tok=3RkMMJWWfF9wsRokuK%2FNZKXonjHpfsX56%2BwpXaCylMI%2F0ER3fOvrPUfGjI4DTctqI%2BSLDwEYGJlv6SgFSLHEMa5qw7gMXRQ%3D

8 Last accessed 17rd Aug, 2013, at http://readwrite.com/2013/06/19/a-handy-guide-to-google-project-loon

information for rescue recovery and survey purposes (Suzuki et al. 2006). It should be noted that with aerial solutions, complex legal issues regarding airspace access and control can arise. Nevertheless, there is a strong argument for deploying balloons in dire situations to meet immediate needs to sustain life.

The above analysis shows that network connectivity to outside of local communities generally require costly tools and/or large-scale national infrastructure that are beyond the reach of local communities. Thus we may conclude that frugal solution design may not useful for connectivity to the outside world.

Bricolage in securing communications to Ofunato

One notable exception we observed was the case of Ofunato where amateur radio provided a means to connect to the outside world. Ofunato City is located in Iwate prefecture, but did not be included in the interviews of 13 municipalities. At the time of the Great East Japan Earthquake, the City lost all communications and was totally isolated from the world. Sagamihara City in Kanagawa Prefecture, far from the disaster area, helped out. This case provides important lessons.

A structural interview to the ICT division of the Ofunato City office was conducted in August 2011, five months after the Great East Japan Earthquake, about the effect of the disaster and how ICT had responded to it.

In the Ofunato City area, the power supply was cut right after the earthquake. The main city office building was not damaged and could be used safely. Though they had an emergency power supply, it was limited to minor functions such as lighting. As a result, ICT could not operate, and the city was isolated from the outside area. Officials faced difficulties in understanding the extent of damage to the city and could not get a handle on what was happening at the time. The only remaining, reliable way to collect information was through personal, official effort. For the two or three weeks following the earthquake, almost all officials in the city office were searching for missing persons. The power supply resumed on March 14, three days after the earthquake, but only for the main office building. City branch offices and evacuation centers were still without power. In the main office, officials used fax and a satellite phone borrowed from the fire brigade to communicate with the outside world. A cell phone company offered a mobile cellular base station, which enabled city officials to access to Twitter on March 18 with five cell phones provided by the same company as well. On March 24, a disaster response center secured a Note PC and an Internet phone connection via satellite. Recovery of lines of communication between the main office, branch offices, and evacuation centers took a long time but partial recovery was achieved by May 21 and the last line was recovered by the end of August.

Channels through which disaster related information could be relayed to residents were restricted to a fire truck, a message board set up in each evacuation center, and notes on paper. An official moved between evacuation centers delivering documents to provide information for supporting people who had escaped the disaster. Evacuee lists and requests for relief goods in evacuation centers were drawn up at each site but homeless people continually moved between evacuation centers, which made it difficult to know their effective whereabouts. This meant that city officials had to journey repeatedly between the main office and evacuation centers.

While Ofunato City struggled with securing additional communication channels between local officials, one of its friendship cities, Sagamihara City in Kanagawa Prefecture, far from the disaster area, helped out. An interview held in November 2011 with an official who was sent as relief staff by Sagamihara City sheds light on the nature of reestablishing communication in a calamity.

"Sagamihara City and Ofunato City enjoy a friendly mutual relationship and hold a festival together once or twice a year. Immediately after the earthquake, seeing that Ofunato was heavily damaged, people in Sagamihara collected contributions to support disaster victims in Ofunato. Sagamihara also sent city officials to help with the recovery in Ofunato. A team of seven left Sagamihara on the evening of March 13 and arrived in Ofunato the next morning. They understood at once that the biggest problem in Ofunato was the virtual communication failure. However, one of the team members belonged to an amateur radio club, and they managed to install amateur radio stations on the roofs of the main and branch offices. Electric power was supplied by emergency power generation. This enabled Ofunato City to communicate with evacuee centers and other branch offices. ”

In summary, Ofunato City augmented its communication means with the help of amateur radio, i.e. with outside support that had not been foreseen.

This indicates the importance of the notion of “bricolage” and preconditions for promoting the collaboration of people using materials readily available at the unexpected events.

We recognize that amateur radio may not be the final solution because of its limited capacity. While it is useful to secure minimal connectivity it would not broad enough to carry large amounts of information seeking whereabouts of individuals and calls for emergency relief. Thus while frugal solutions may not be the final solution for securing connectivity to the outside, it should be incorporated in the planning as a useful tool to augment other means.

7-1-2: Connectivity within the community

Second, likely candidates for connectivity between hubs and individuals are Wi-Fi and direct access to the satellite and Bluetooth. Regarding to secure communications with Bluetooth, we can see recently interesting example in Hong Kong.

Securing communications in Hong Kong

During student protestors that occurred in 2014 in Hong Kong, student secured communication with each other by using a smartphone app called FireChat.[9] Since this app uses Bluetooth and is underpinned by mesh networking, it enables communication with anyone who is in range of 200 feet (60m). Although the authorities in Hong Kong did not limit connectivity, students connected through this channel because they were afraid of shut off communications.[10] FireChat can't be shut down because it doesn't depend on the mobile carriers' networks to send messages, but instead coordinates all Wi-Fi and Bluetooth communications on the FireChat protesters' smartphones into a single mesh network. FireChat can also use the cellular and 4G networks, but operates independently of the core infrastructure if the public networks became unavailable.[11]

This kind of connectivity is called as "Community-built solution," [12] allows people communicate within its bounds in case connectivity between hubs and outside goes down. It might work well in emergency scenarios. This approach realizes frugal solutions in inexpensive ways. It is also a powerful example of self-organization of a movement through the use of mesh networking. These mobile self-organizing networks (Robertazzi et al. 1986) has huge possibilities for future communications within the community during a disaster

9 Last accessed Dec.30th 2014, at http://channeleye.co.uk/hong-kong-protestors-use-smartphone-app/

10 Last accessed Dec.30th 2014, at http://channeleye.co.uk/hong-kong-protestors-use-smartphone-app/

11 Last accessed Dec.30th 2014, at http://www.networkworld.com/article/2691105/opensource-subnet/mesh-networks-and-firechat-how-hong-kong-protestors-are-keeping-communications-alive.html

12 Last accessed Dec.30th 2014, at http://www.fastcolabs.com/3020680/how-to-build-a-low-cost-wifi-mesh-network-for-emergency-communication

situation. We can confirm, then, bricolage is one requirement that enables responding to the unpredictable. A universal design that enables bricolage to be exploited should be made a system feature. A system should be able to exploit whatever materials are at hand to create capabilities and resources for disaster relief.

The overarching criterion for the usefulness of a potential technology for immediate disaster relief is whether it has the functionality and cost structure to make it part of a person's daily life. Municipal governments are under severe budget constraints, and they cannot assume large costs for technologies that are used only on very rare occasions. Technologies with pricing structures that deter daily use have limited success in disaster situations. We definitely need to develop frugal connectivity between hubs and outside for the future. On the other hand, as for connectivity between the hub and individuals we can choose an inexpensive way by using smartphones, with which we are already familiar.

This implies there is a need to use a wireless network and associated devices not only as an emergency backup but also in normal daily operations. While recognition of the importance of wireless has become stronger among the municipal governments after the Great East Japan Earthquake, its adoption by municipal government systems has been slow. We need technical, legal, and organizational measures to allow a smoother introduction of wireless systems in municipal government information systems.

Analysis in this section suggests that a frugal solution approach may be applicable in preparing connectivity at the community level. It is possible to use Wi-Fi, Bluetooth, or whatever is available to establish basic local area communications. In a severe disaster situations when help from outside is not available, the possibility of bricolage to create frugal solution is encouraging. Thus it is a recommendation that such approach should be considered as a serious option.

7-2: communication channels used in various disaster situations

Design principles that are shown in the previous chapter cannot be generalized perfectly because they are derived from only one disaster situation. To overcome the limitations, the strengths and weaknesses of the notion of frugality are evaluated by looking into communication patterns in other types of disaster and comparing them with communication patterns in earthquakes. Clarifying the strengths and weakness leads to new directions which we should take in the future (Brown 2008).

Here the situation for evaluating the notion is the process of information sharing during a disaster. Provision of information to its residents during a disaster is one of the important duties with which municipalities are charged. In terms of organizational resilience, as Horne (1998) identifies seven major streams such as community, competence, connections, commitment, communication, coordination, and consideration. Community, connections and communication are considered deeply related to information sharing. Following the Great East Japan Earthquake, residents were generally dissatisfied by the level of information access to local services and officials related to the relief operation. A Japanese private research company conducted a survey in April 2011 on people's satisfaction regarding getting information during the earthquake, which shows that almost 60 percent of evacuees at evacuation centers were dissatisfied with the process of getting information.[13] Anxiety caused by the many disaster-related problems was in no way alleviated.

Communications modes are normally degraded during disasters (Simmons et al. 2003). During Hurricane Katrina in 2005, organizations in charge of recovery could not find any effective means of communication, especially in the first three days after the hurricane (Comfort et al. 2006). We had almost the same situation during the Great East Japan Earthquake. Municipalities struggled with securing communication channels to its residents. Since information procedures are important in efficient operations of organization (Boulding

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[13] Last accessed Nov.10th 2014, at http://www.surece.co.jp/src/research/area/pdf/20110311_miyagi.pdf

1956), one of the reasons that municipalities failed to satisfy people with the process of getting information was caused by its difficulties in securing communications.

Survey research to understand how municipalities secured communications during disasters

To understand the requirements of communication systems in such calamities including other types of disasters, I conducted a questionnaire survey (appendix-3) on the means of communication between municipal offices and residents from August to September 2011. This survey also took into account disasters such as heavy rain and earlier earthquakes. The object of this survey was to determine the characteristics of responses to different types of disasters and to understand "the patterning of human action inside work organizations" (Dutton et al. 2006; Weick 1979). The surveyed target area included municipalities throughout the entire nation, not only those strongly affected by the Great East Japan Earthquake. Questionnaires were sent to all 1,746 Japanese municipalities and 280 valid forms (16%) were returned.

To assess chronological variation in disaster recovery, questions were asked applicable to three chronological stages: within 24 hours, from 2 days to 3 days (after a disaster), and from 3 days to 7 days (after a disaster). The two key questions were: (1) what kind of information was collected and transmitted, and (2) what channel was used to collect and transmit that information. A breakdown of answers by disaster type was 115 answers citing earthquakes (including any other earthquakes that happened before the Great East Japan Earthquake) and 67 citing heavy rain (typhoon), while 2 citing landslide disasters and 96 came from respondents who had never experienced disasters and who were asked to base their answers on their own assumptions.

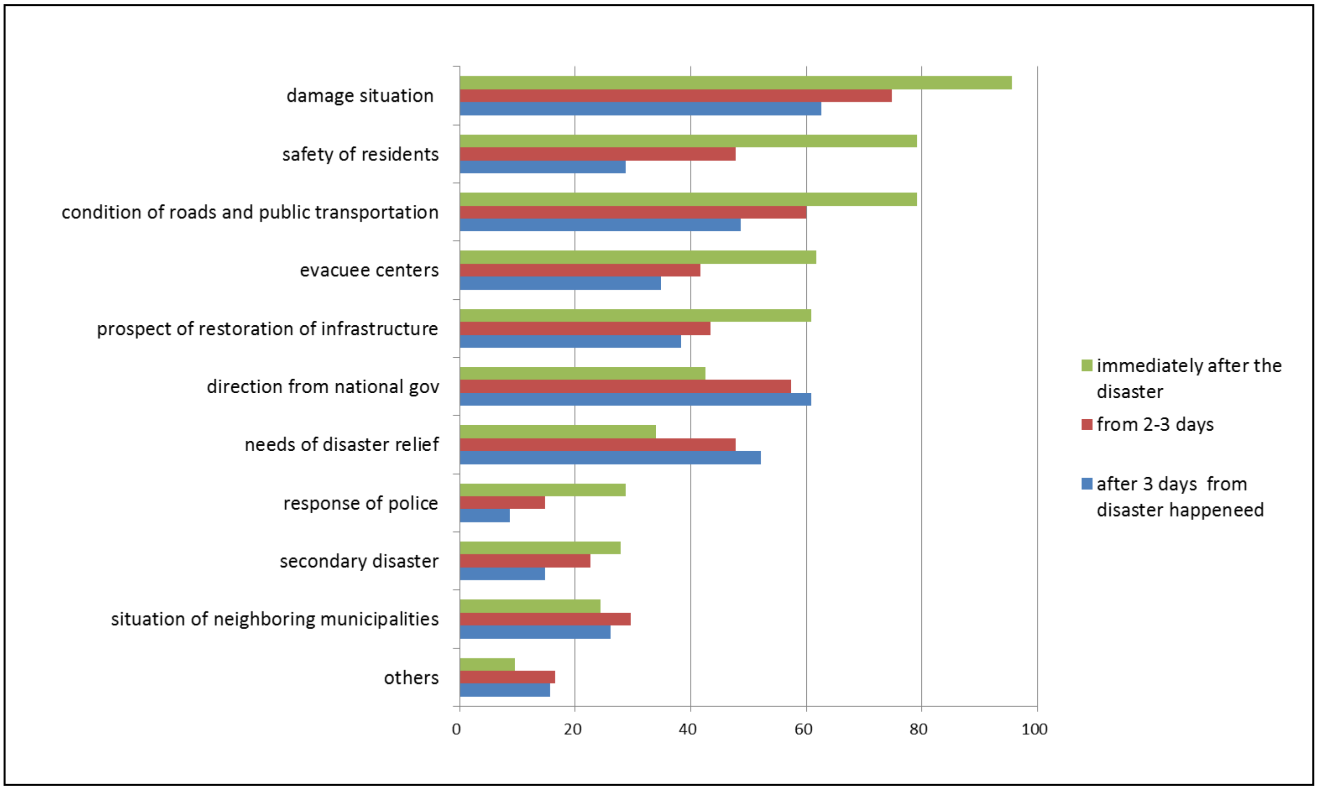
So far, in order to respond to a disaster effectively, the national, prefectural, and municipal governments have implemented disaster-proof channels such as satellite phones and external public announcement systems linked to an emergency alert system. These channels require a huge quantity of power and are for use in disaster situations rather than for daily routine tasks.

During a disaster, municipalities are virtually the sole source of information concerning damage and recovery for their residents. Therefore, municipalities should collect accurate information and be in a position to transmit it effectively. However, can these disaster-proof channels really be called effective? A disaster-proof channel takes its position on the opposite side of the notion of frugality. The following part of this section shows the reality in the way of collecting and transmitting information by municipal governments.

7-2-1: Information collection

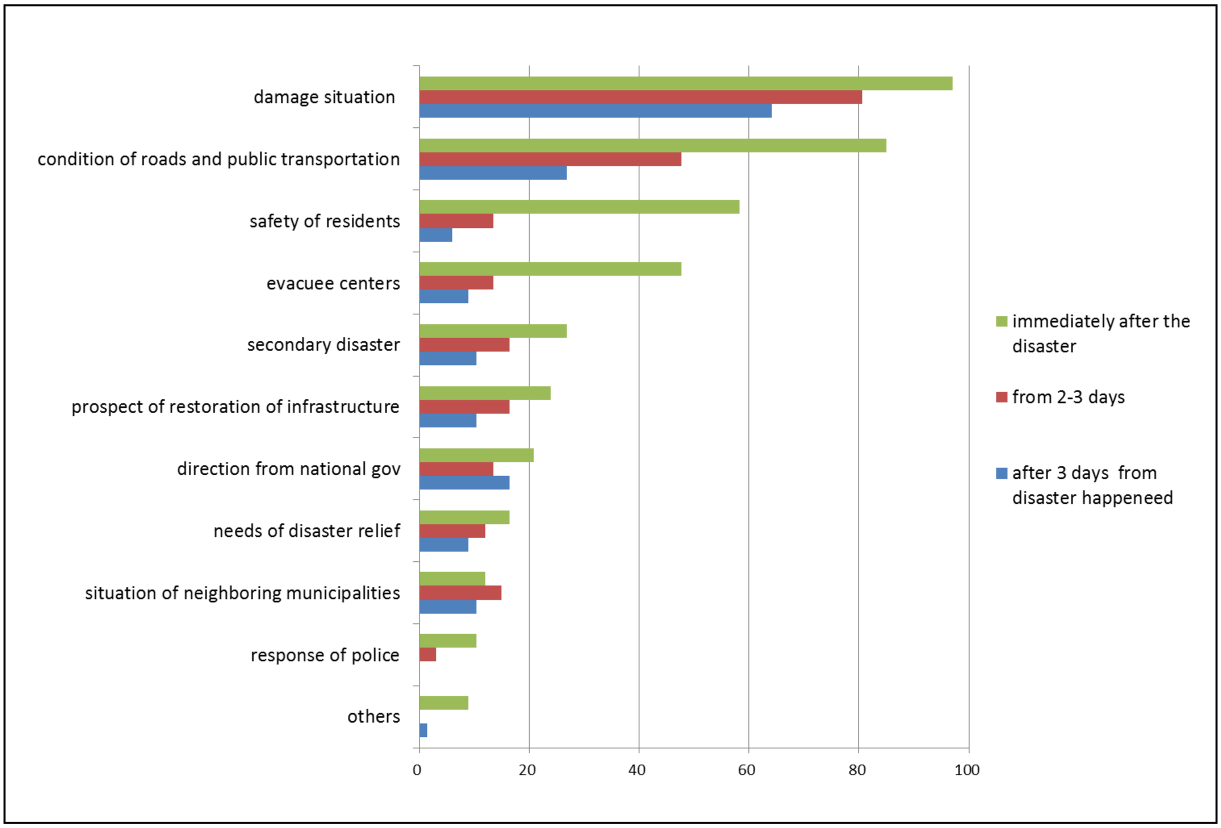
A characteristic of the earthquake category shown by the result is, information that needs to be collected changes as time passes (Figure 12). Information about the damage situation, the safety of residents and the condition of roads and public transportation are imperative, demanded immediately after the earthquake, however, as time passes, demands to get to know the needs of disaster relief increases. Direction from the national government also becomes important.

Figure 12: Information needed to collect in earthquake category (n=115, multiple answers, %)



In the heavy rain category, the trends are the same as in the earthquake category. There are the immediate demands for information about the damage situation, the condition of roads and public transportation and the safety of residents. However, a chronological change of information requirements does not appear (Figure 13).

Figure 13: Information needed to collect in heavy rain category (n=67, multiple answers, %)



Then, to understand which channels municipalities used to collect the above information during the disaster, the following 23 items were asked.

> Question items for channels used to collect information: community FM, internal mail, AM radio, mobile phone's mail, newspaper, internal network, internet email, satellite phone, cars, mobile phone, FAX, internet, TV, police, fixed phone, fire brigade, officials, J-Alert[14], message board, twitter, blog, SNS and, others

14 J-Alert is founded by the national fire and disaster management agency to transfer emergency information through a satellite to all municipal governments.

The top five ranked items in each time series are shown in table 11 and 12. As the number of answering "officials" is extremely high in every chronological phase, this item is excluded in the ranking. An official is the most reliable and certain channel in a degraded ICT environment.

Table 11: Ranking of channels for information collection in earthquake category (n=115, multiple answers, %)

Immediately after the earthquake (~24hours)		**After 2days to 3days**		**After 3days to 1 week**	
Fire	60%	*Phone*	64.3%	*Phone*	64.3%
Phone	47%	*Fire*	44.3%	*TV*	46.1%
Police	40.9%	*Mobile phone*	35.7%	*FAX*	37.4%
TV	35.7%	*TV*	31.3%	*Mobile phone*	35.7%
Internet	25.2%	*FAX*	31.3%	*Fire*	35.7%
*Officials	72.2%	*Officials	57.4%	*Officials	50.4%

Basically, a private wireless network is built between municipalities and the fire brigade. When a disaster happens, a local disaster management plan directs communications using this wireless system. In reality, the channel most frequently used in the week following the disaster is the fixed phone. Two days after an earthquake, the usage of mobile phone increases. FAX is being used less in ordinary operations because of the diffusion of e-mail, however, demands for FAX services peaks during a disaster. This is because disaster response head-quarters in municipal government have strong tradition of using paper documents for their decision making.

In the heavy rain category, fixed phone, fire brigade, police, mobile phone, internet and FAX are used with similar frequency as in the earthquake category.

Table 12: Ranking of channels for information collection in heavy rain category (n=67, multiple answers, %)

Immediately after the earthquake (~24hours)		**After 2days to 3days**		**After 3days to 1 week**	
Phone	56.7%	*Phone*	44.8%	*Phone*	35.8%
Fire	53.7%	*Fire*	29.9%	*Mobile phone*	23.9%
Police	38.8%	*Mobile phone*	25.4%	*Fire*	22.4%
Mobile phone	35.8%	*Police*	22.4%	*Police*	13.4%
Internet	34.3%	*Internet*	20.9%	*FAX*	13.4%
*Officers	80.6%	*Officers	71.6%	*Officers	53.7%

In order to determine in which situation disaster-proof channels are effective, channels are separated into two categories such as disaster-proof channels and daily-use channels. Disaster-proof channels include the fire brigade, police, satellite phones, message boards, cars and emergency alert systems. On the other hand, daily-use channels refer to fixed phone, mobile phone, fax, email, the Internet, and TV.

The following figures show the mean frequency of usage of each category of collection channels by chronological stage.

Figure 14: The mean frequency of usage of collection channels in earthquake category

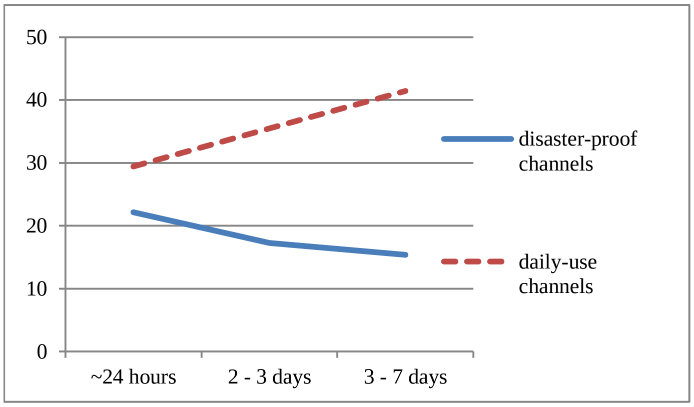
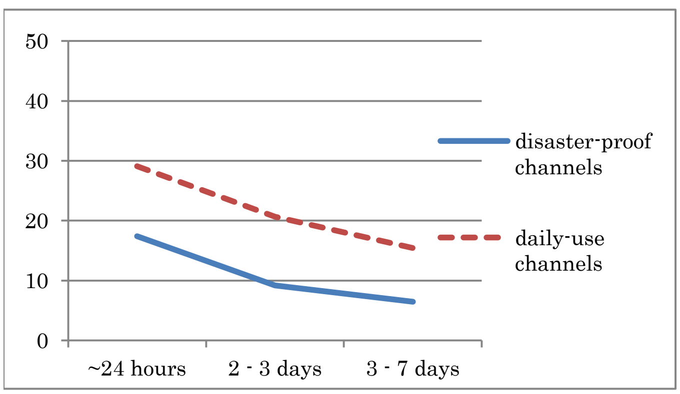


Figure 15: The mean frequency of usage of collection channels in heavy rain category



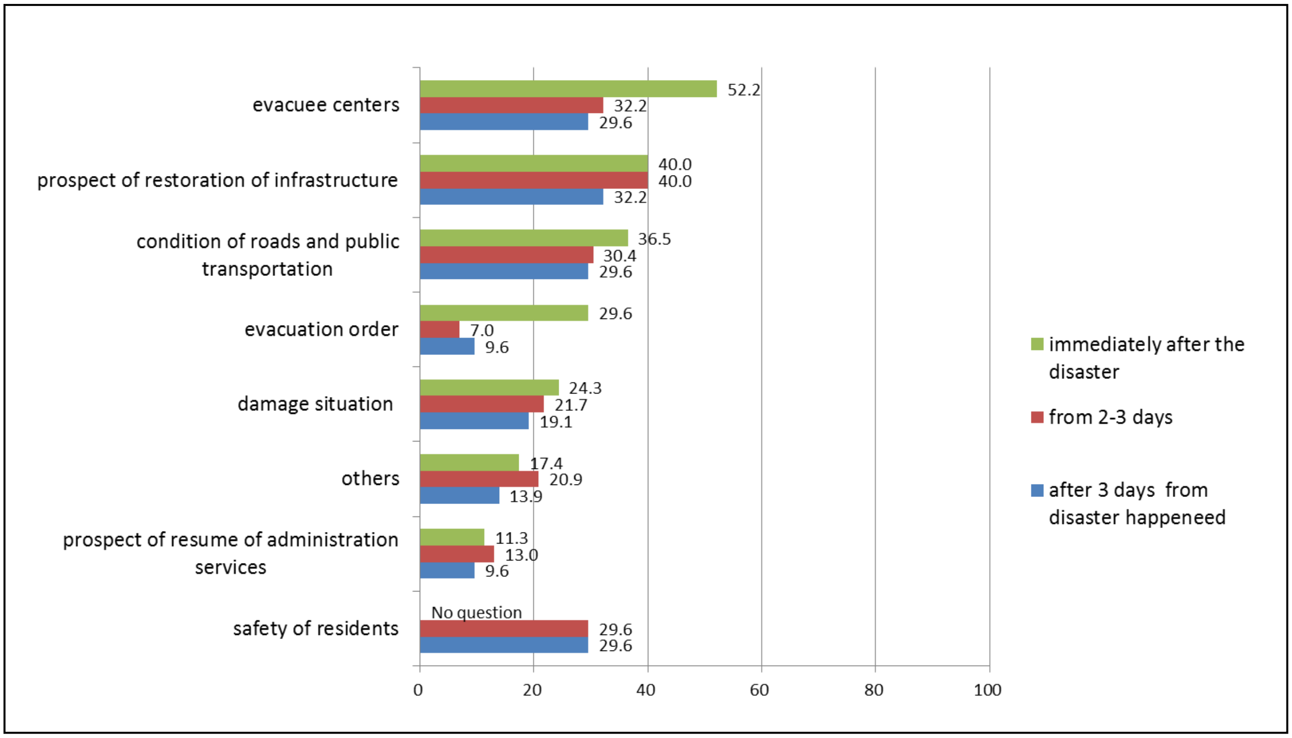
Results of a Wilcoxon signed-rank test indicate a statistically significant preference for daily-use channels in every chronological stage (Earthquake within 24 hours: $p=0.017$; from 2 days to 3 days: $p<0.0001$; from 3 days to 7 days: $p<0.0001$; heavy rain within 24 hours: $p<0.0001$; from 2 days to 3 days: $p<0.0001$; from 3 days to 7 days: $p<0.0001$).

The biggest difference between an earthquake and a heavy rain disaster is predictability. Earthquakes cannot currently be forecast, but there are advance warnings for heavy rain, and thus earthquakes tend to become large-scale disasters and their effects last longer than those of heavy rain. For unexpected disasters, such as an earthquake, the usage of daily-use channels in collecting information increases with the passage of time.

7-2-2: Information transmission

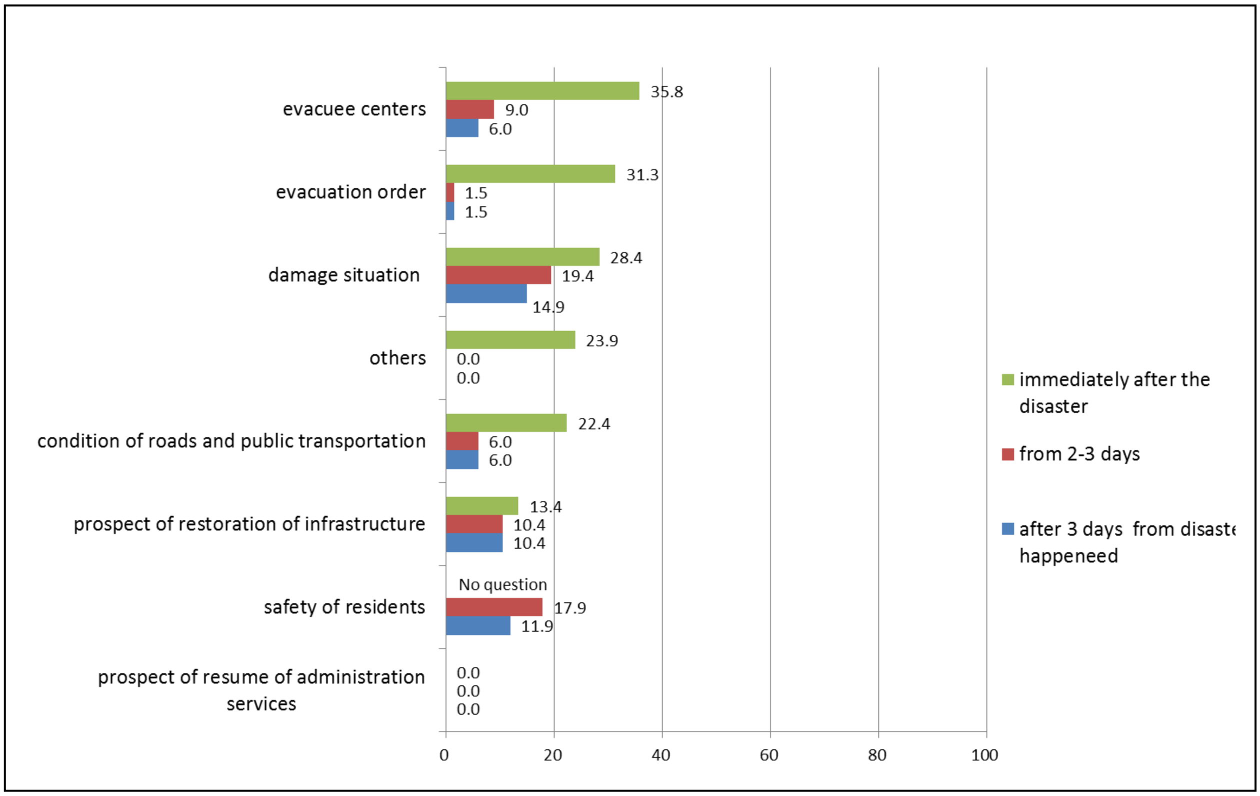
As for information transmitted by municipalities to its residents during an earthquake, figure 16 shows that immediately after, and in the week following an earthquake requires information about the evacuee centers, the prospect of restoration of infrastructure, and the condition of roads and public transportation. By the second day, municipalities are getting a huge amount of inquiries about the safety of residents. Therefore, information on safety of residents scores highly in this phase. The answer of "others" includes information on nuclear power plant accidents and planned power cuts that were conducted to save energy after the Great East Japan Earthquake.

Figure 16: Information transmission by municipalities in earthquake category (n=115, multiple answers, %)



In the heavy rain situation, the result appears to differ (figure17). Information traffic regarding evacuation information predominated, however, if restoration of infrastructure and public transportation is not heavily damaged, less information related to these topics is required.

Figure 17: Information transmission by municipalities in heavy rain category (n=67, multiple answers, %)



Channels most used to transmit the above information are public announcement systems and home pages. Respondents were questioned about the following 16 items.

Question items for information transmission: fire trucks, prefectural disaster wireless, a prefectural disaster system, an public announcement system[15], an internal receiver[16], community FM, mobile phone's mail, internet email, disaster message board, home page, twitter, blog, SNS, cars, officials, and others

The top 5 ranked channels do not change over time (table 13). In other words, municipalities strongly rely on limited items such as public announcement systems, home pages, cars, an internal receivers and mobile mail. A local disaster management system assumes the primary usage of public announcement systems and internal receivers for information transmission during a disaster. In reality, they were used quite well. However, residents were dissatisfied especially with public announcement systems because they are hard to hear what the announcement is.

Table 13: Ranking of channels used for information transmission in earthquake category (n=115, multiple answers, %)

Immediately after the earthquake (~24hours)		**After 2days to 3days**		**After 3days to 1 week**	
Public announcement system	55.7%	*Home page*	44.3%	*Home page*	48.7%
Cars	40%	*Public announcement system*	37.4%	*Public announcement system*	36.5%

[15] A public announcement system is normally set up in outside. 

[16] An internal receiver is distributed by municipalities to receive announcement from a public announcement system. 

Home page	37.4%	*Cars*	30.4%	*Cars*	22.6%
Internal receiver	33.0%	*Internal receiver*	20.9%	*Internal receiver*	20.9%
Mobile mail	20%	*Mobile mail*	20%	*Mobile mail*	20.9%
*Officers	23.5%	*Officers	19.1%	*Officers	16.5%

The heavy rain category shows the same trend (table14). The only difference is the peak demand period for these channels to transmit information is during 24 hours after heavy rainfall episodes. Around 2 days after the episode, the result shows less usage of any channels. The most important phase of information transmission in the heavy rain situation is immediately after a disaster hit the area.

Table 14: Ranking of channels used for information transmission in heavy rain category (n=67, multiple answers, %)

Immediately after the earthquake (~24hours)		**After 2days to 3days**		**After 3days to 1 week**	
Home page	34.3%	*Home page*	13.4%	*Home page*	10.4%
Mobile mail	29.9%	*Internal receiver*	9%	*Internal receiver*	4.5%
Internal receiver	29.9%	*Public announcement system*	6%	*Public announcement system*	3%
Public announcement system	26.9%	*cars*	6%	*Community FM*	3%
cars	22.4%	*Mobile mail*	4.5%	*Mobile mail*	3%
*Officers	19.4%	*Officers	6%	*Officers	3%

The following pair of figures shows the mean frequency of usage of each type of transmission channel by chronological stage. In this category, disaster-proof channels include the fire trucks, a prefectural disaster system, a public announcement system, an internal receiver, and cars. Daily-use channels comprise community FM, mobile mail, Internet mail, home page, and twitter.

Figure 18: The mean frequency of usage of transmission channels in earthquake category

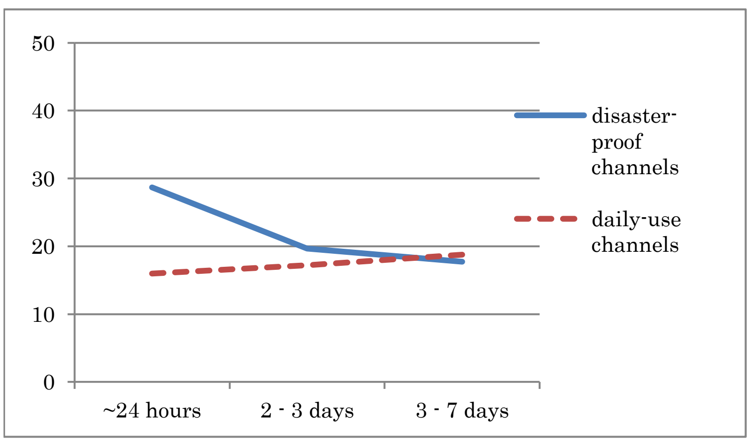
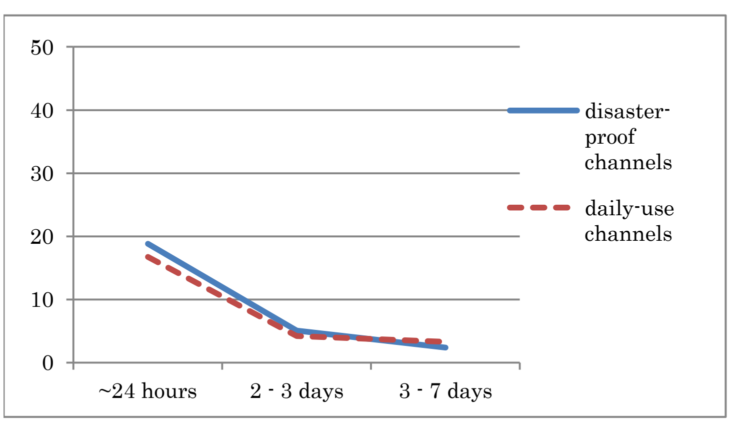


Figure 19: The mean frequency of usage of transmission channels in heavy rain category



Only results covering the 24 hours following an earthquake show a statistical difference on the Wilcoxon signed-rank test (Earthquake within 24 hours: $p<0.0001$; from 2 days to 3 days: $p=0.292$; from 3 days to 7 days: $p=0.568$; heavy rain within24 hours: $p=0.431$; from 2 days to 3 days: $p=0.541$; from 3 days to 7 days: $p=0.603$).

Compared to the results for information collection, the figures for transmission show municipalities rely more on disaster-proof channels. However, in the earthquake category, daily-use channels get used more for transmissions as time passes. We also observe that in the case of earthquakes, the same trend applies to both information collection and transmission. This means information demand continues for a long time in the event of unpredictable disasters but decreases relatively rapidly under predictable conditions.

Conventional robust systems (disaster-proof channels) need to be especially effective within the first 24 hours following a disaster. However, such effectiveness cannot be guaranteed in the event of unpredictable catastrophes. While considering how to deal with an unexpected power or connectivity failure, officials may naturally search for familiar and frugal ways of handling it.

7-2-3: Implications of the differences

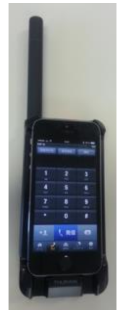
The survey research showed a clear difference in the communication patterns in earthquake and heavy rain situations, and the reliance on daily use media in the prolonged situations in earthquakes. This suggests that frugal solutions are particularly useful in prolonged damage situations.

The survey results showed people getting back to “habituated ways” when they have to produce a response under pressure (Weick 1993). This trend of finding solutions in one’s regular situation appears strongly, especially in a situation where pressure continues for a certain period. It also became clear that disaster-proof channels were used especially in the immediate response stage (within 24 hours of a disaster). These results lead us to stress the importance of finding the right balance between daily-use and disaster-only channels. This means the notion of frugality is not enough to satisfy all communication requirements.

A problem that has troubled municipalities for a long time is the high cost of preparing disaster-proof channels such as external public announcement systems and satellite phones. Building a master station for a public announcement system costs around USD 60,000. A relay station costs half that amount and an outside speaker costs around USD 3,000. In addition, installations require monthly maintenance with a cost of around a few hundred USD for each speaker. A satellite phone costs up to USD 2,000 for a single device and the service fee is around one hundred per month. Usually the national government compensates for the initial cost of installation though operating costs must be paid by municipal governments as long as the system is kept running. These channels are developed and used only in a disaster situation, which greatly limits the opportunity to train on them. When officials do need to use these channels, they may have problems operating them due to lack of familiarity.

Combining daily-use and disaster-only channels would be a useful solution to this problem. For example, the Japanese mobile company, Softbank Mobile Co., launched a new satellite phone called 202TH in 2014, which can be used in conjunction with the iPhone. A solid, hand-held bracket firmly holds the iPhone in place and connects to it via Bluetooth using a special application called "SatSleeve." This enables the iPhone to be used as a satellite phone: making calls by phone number lookup, sending text messages, and transmitting data. Its initial and operating costs are almost half of a conventional satellite phone. This illustrates the possibility of daily-use channels as the foundation for multi-functional cover. We should exploit familiar channels as the foundation of disaster recovery and relief communications.

*202TH with iPhone



Photos by the author

Both intuitive and smooth procedures for disaster relief tasks are important during catastrophic events, because they enable collaboration among players in the field and reduce complexity (Perrow 1983; Perrow 1984). As it was explained in the end of chapter four, the following two approaches for designing systems have been proposed (Banzhaf 2004): (1) a traditional design that contains complex principles and rules, and (2) an evolutionary design that contains a random combination of structural elements and follows simple design principles. Perhaps we should follow simple design principles that reflect our daily life.

7-3: Reality of using citizens' own device (BYOD) in disaster relief operations

The ubiquity of smartphone is apparent. According to a 2011 survey by the Japanese Ministry of Internal Affairs and Communications[17], the diffusion of mobile phones for Japanese households is 95 percent, of which smartphones are 29 percent. The percentage of households with smartphones is rapidly increasing. It was 10 percent in 2010 and became almost three times as much in one year. Mobile-cellular penetration rates stood at 96 percent globally, 128

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[17] Last accessed Sep. 3rd 2014, at http://www.soumu.go.jp/johotsusintokei/whitepaper/ja/h24/html/nc122310.html

percent in the developed world, and 89 percent in the developing world in 2013[18]. Smartphones are rapidly becoming a standard platform for people's everyday lives, and thus a suitable foundation for disaster recovery in Japan and many other countries.

We should recognize the importance of training such devices effectively in a disaster situation.

7-3-1: The Drill

A fire drill which realizes a part of whole design principles using smartphones was conducted in November 2014 in Tome City, one of the municipalities damaged in the Great East Japan Earthquake. As it is discussed in the previous chapter, because smartphones realize the four information drives of a frugal system, we used them as the foundation of the communication system of this fire drill. A smartphone is a universal device, has a ubiquitous network connection, has a phone number to provide uniqueness, and has a connection to a database, which enables information unison. At the same time, use of citizen owned device means integration of systems that are under control of diverse range of people. Such integration may be difficult when people are using different versions of operating systems and/or devices with various sizes of screens.

The initial test was planned with the operation of evacuation centers, which would test the use of smartphones for supporting disaster relief. It intended to involve the use of three key functions; (1) identification and registration of people at evacuation centers by phone number or SIM ID, (2) recording people's arrivals and departures and, (3) creating an evacuee database. Using a smartphone's number, the application can transmit information to people who need specific information, such as medicine or milk for infants.

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[18] Last accessed Sep. 3rd 2014, at http://www.itu.int/en/ITU-D/statistics/Documents/facts/ICTFactsFigures2013-e.pdf

The fire drill involving citizens (and city officials playing the role of citizens) was conducted with following operational flows.

(In the in advance preparedness)

> A dummy unison database was prepared in advance and available to be accessed through a smartphone (universal device) application

(In the initial response training)

> In each evacuation centers, evacuees registered their location to the application (to provide information uniqueness)
>
> Evacuees send their demands for relief goods such as water, food, medicine through the application
>
> An evacuee database was created automatically and officials were able to refer the evacuee list and needs for relief goods

7-3-2: Assessment of the results

The drill was accomplished smoothly because people were already familiar with the devices and easily got to understand how to use it in the operations. However, the result of the drill was mixed. Starting from the primary interest of this chapter, the use of smartphones for accessing the database, was accomplished. In this regard we verified that it is certainly a possibility, although the scalability of the system should be questioned because of the limited number of smartphones tested.

We should also report the failures, identification of evacuees with using phone number of SIM ID was not realized because of a privacy issue. To compensate, a dummy database was created in advance and once the fire drill started, evacuees logged in the application and updated their status (location) by themselves. We should also note that we did not conduct any connectivity measures in this drill. Rather we simply assumed continuous network connectivity.

Although it was dummy information we confirmed the importance of preparing a unison database which every relief staff could access, and providing information uniqueness on the database. These enabled smooth information sharing among different sites at the same time. This list would be useful with exported as a csv file and be editable.

While noting limitations, we conclude that a frugal solution that employ devices that citizen use for daily lives are worth incorporating in the lists of options to save citizens' lives under severe disaster conditions. We also note that in order for such an approach to work, we need security measures to protect the privacy of citizens.

7-4: Conclusion of the evaluation

Since this paper proposes the frugal design for realizing a resilient IS, we should assume network failure and consider alternatives. While the connectivity within communities will have to depend on bricolage, connection to the outside world requires large-scale systems that are costly. Building frugal network connecting to outside of the damaged area would be the biggest hurdle for the proposal.

Survey result shows different trends in securing communication channels by municipalities between earthquakes and heavy rain disasters. An earthquake, whose effects tend to last long, requires familiar tools to access information. One situation where it is effective is when an overwhelming and prolonged disaster isolates the local communities forcing them to provide their own solutions. On the other hand, in heavy rain situations, information needs are not prolonged and municipalities tend to rely on disaster-proof channels especially immediately after (within 24 hours of) the disaster.

Field drill using smartphones suggest that the frugal solutions that employ citizen owned devices that they use for everyday life, is worth considering.

In view of the recognition that frugal solutions may be effective in certain situations but not in others, and that various kinds of disaster may happen anywhere, a recommendation will be to take a hybrid approach. This means preparing “dependable” systems that resist interruption, while recognizing the importance of frugal/creative solutions and be ready to use them. One good example of this hybrid approach is a mobile satellite phone that can be functional when it is used in conjunction with the iPhone. This example shows the possibility of using our own device as the foundation for multi-functional systems. From this point of view, we can see the future opportunity for developing connectivity to outside the area with combination of existing technologies. This is not the perfect example, but we see Ofunato City augmented its communication means with amateur radio, which was brought to them by its friendship city. It implicates the possibility of bricolage, producing something from what’s available, by relying on people’s capacity to improvise in the face of uncertainty (Baker et al. 2005). An amateur radio is not new technology and disasters did not provide the impetus for developing it in the first place. It was simply available and required little power to run. Since developments of drones operated with smartphones are growing recently, use of drones to carry communication base stations is a likely candidate for regaining ubiquitous connectivity.

Chapter Eight

Contribution and Limitation

Following the Great East Japan Earthquake, there has been a lot of discussion in Japan about building a disaster-proof society. The earthquake was perhaps the harshest possible challenge to an information society. It made Japanese leaders and citizens acutely aware of how much daily life depends heavily on ICT infrastructure. Disaster recovery operations to help people in stressed times must rely on ICT. Then, what does a disaster-proof really mean?

This paper presents research into the effect of natural disasters on ICT and the need for a resilient IS in municipal governments. Three key IS problems which should be solved for handling future disaster situations are identified from empirical research on the Great East Japan Earthquake.

The first problem was infrastructure failure, especially power and communications. In many areas, electric power and connectivity were lost at the most critical lifesaving phase (i.e., immediately after the earthquake). Also, we discovered that up to four months were required to recover power and communications in some areas. No one had expected such failures would last for such a long.

The second problem concerning the diversity of IS needs that surfaced after the basic infrastructure such as power and telecommunication was restored. Since crisis situations were diverse depending on time and location, we saw different needs for IS in the field. Of particular importance is the recognition that operations of municipal governments are very different in disaster situations from normal day operations. ICT should support critical lifesaving operations to meet the diverse needs of citizens. Awareness of such special needs existed prior to the Great East Japan Earthquake. In fact, the nationally planned disaster relief software package existed and was offered for free to municipal governments. Unfortunately, however, they were overwhelmed by the diversity of the needs. Instead of using the planned solution, several autonomous system developments emerged that filled the needs of municipal governments to meet the various demands of the residents.

The third problem was the confusion created by the multiple autonomous responses. While these systems were developed to meet the immediate needs, data compatibility among these systems was lacking. This caused delays in relief efforts and subsequently hindered recovery. In other words, fragmentation of data seriously damaged the efficiency and consistency of relief efforts.

To solve these problems, this paper sets goals on designing systems resilience, *quickly gaining essential capabilities to perform critical post disaster missions and to smoothly return to fully stable operation thereafter*. Essential capability must be employed for conducting disaster relief operations such as confirming the whereabouts and safety of residents, providing residents with information, establishing and operating evacuation centers, transporting and managing relief goods, and supporting evacuees and creating evacuee lists. These tasks are different from the daily operations of municipal government, and other ordinary tasks were suspended to meet the impending and mounting needs of citizens.

Here the question is, how should we design the future technologies and processes of information systems to gain essential capabilities to conduct disaster relief operations? Based on the three key IS problems, a resilient IS design must ensure (1) swift recovery after functions fail, (2) a creative response, and (3) the integration of creative responses that occur independently. With the purpose of realizing these system requirements, this paper proposes a three-stage model based on a chronological sequence employs in structuring the proposed design principles. The three-stage model consists of “in advance stage,” “initial response stage” and “recovery stage.” The notion of a frugal information system (Watson et al. 2013) that is developed and deployed with minimal resources to meet the preeminent goal of the client provides a foundation of design principles. Since we are forced to deal with limited access to resources during a disaster, frugality plays an important role in realizing a resilient IS.

In the in advance stage, preparation of ubiquitous networks and unison databases is essential. While this paper emphasizes the role and importance of a creative response to deal with unexpected events, it does not assert that preparation is meaningless. Rather, it emphasizes the importance of adopting open and standard technologies for our peacetime systems so that data from the system can be extracted and used by creatively developed systems in the field.

These days, we can assume network connectivity everywhere. We can also assume that most people own universal devices, which are able to connect to the network easily. Databases should include static characteristics, such as residents' medical information and household membership details. These data should be linked in the database that would be used in the initial response stage. This helps in maintaining unison and uniqueness of information when data from multiple systems are merged in later stages of disaster recovery.

In the initial response stage, municipalities need to deal with situations without support from outside of the damaged area. It was necessary to use universally available and versatile devices that require minimal resources. In addition, these devices should be those that people already have and with which they are familiar in order to promote a creative response in the field. Data that are collected during the initial response should be dynamic. These data must employ uniqueness to identify people or entities by their characteristics, location, and time. This would make it easier to understand a situation and to connect with information collected by other sites. Smartphones are considered as a universal device.

The initial response gradually becomes a recovery as efficient support for disaster relief arrives in an area. As municipalities' disaster relief operations are quite distinct from normal day-to-day tasks, the requirements for information systems become different as well. It should recover quickly and support a creative response in the field. It is thus natural to return to the conventional systems designed for normal use. However, the experiences of the earthquake indicates the importance of (1) a seamless transfer of the recording of each resident's situation with unison from temporary systems to the normal use systems, as well as (2) data compatibility among systems for normal operations.

The test of generalizability of frugal solutions suggests that it may be effective in certain situations but perhaps not in other situations. Thus, the recommendation of this paper is to take a hybrid approach, in which more traditional disaster prevention approach is combined with the preparation for frugal solutions to make the system more resilient overall.

8-1. Theoretical contribution

Conventional business continuity plans assume to maintain their business at times of extraordinary stress. The official guideline of BCP drawn up by the national government followed this principle. However, municipalities' disaster relief operations are quite distinct from normal daily operations and only come into focus when a disaster happens. Different types of demands and responses should emerge in such an environment, and it requires different levels of capacity in the system (Comfort et al. 2004).

Discussions in contemporary IS research appear to be mainly based on the idea that IS reliability is achieved through the use of dependable technology (Butler et al. 2006). Assuming reliability, the effectiveness of systems and processing capacity is given much attention. This focus, however fails to account for the infrastructure needs for IS operations in unexpected and overpowering situations. During the Great East Japan Earthquake, no one had predicted that power supply and network connectivity would be lost for such long periods. This outcome made it clear to us that achieving perfect reliability is improbable. Here an important question is which features of system can improve capability which leads human behavior to be creative.

The notion of resilience assumes adaptive capacity that allows for continuous development, like a dynamic adaptive interplay between sustaining and developing with change (Anderies et al. 2004; Berkes et al. 2003; Folke 2006; Zolli et al. 2012). Resilience thus involves identifying core missions that have to be performed under emergency situations, and applying whatever means available to achieve the key objectives. It is about continuously anticipating and adjusting to new situations and having the capacity to change the situation (Hamel et al.

2003). That is quite different from trying to maintain its performance “as usual” under adverse conditions. Then, this paper defines resilience as quickly gaining essential capabilities to perform critical post disaster missions and to smoothly return to fully stable operation thereafter. The next question is, how can we realize resilience through IS design?

The literature discusses organizational resilience is achieved by Normal accident theory and High reliable organizations (HRO) theory (Barton et al. 2009). Normal accident theory suggests that the best approach to improving system reliability and safety is to change the system itself (Perrow 1984). Since this discussion is based on an assumption that the combination of interactive complexity and tight-coupling within a system will inevitably lead to failure and accidents, to reduce its complexity or tight coupling becomes an essential drive. High reliable organizations theory (La Porte 1996; La Porte et al. 1991) explains organizations are supposed to employ abilities to prevent and to manage mishaps before they can spread throughout the system causing widespread damage or failure. This theory suggests that reliability and safety are achieved through human processes and relationships, rather than through changes to the system structure (Roberts et al. 1994).

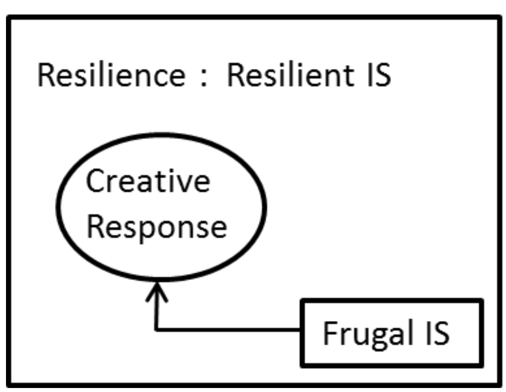
In reality, since systems complexity caused the delay of its recovery in Otsuchi Town during the Great East Japan Earthquake, the importance of reducing complexity was reconfirmed. However, implication of Normal Accident Theory is not enough to explain how to realize resilience. With a same reason, HRO did not success to explain the way to provide an adaptive capability through IS design during disaster situations.

This paper introduced the notion of frugal IS (Watson et al. 2013) that employs four information requirements such as universality, ubiquity, uniqueness, and unison. Universal usability, multi-functionality and interoperability are key concepts of “universality.” This encourages using open systems that can be readily integrated. “Ubiquity” requires access information unconstrained by time and space. If ubiquitously available smartphones, standard PCs, and non-dedicated public Internet services can be used, the chances of creatively developing disaster relief systems with “whatever available” resources increase. This will empower stranded people to help themselves before outside helps arrive. Information that will likely be shared during disaster relief operations should employ the notion of “uniqueness.” This means recording attributes (such as the profiles and location) of a person or entity. This is essential to identify objects. Time will frequently need to be recorded to uniquely identify events and track their relationships. “Unison” indicates the importance of consistency of data among different locations and databases. This would be the most essential factor to prevent the lack of data compatibility. This also enables people to share information with any devices at any time.

These system design principles are considered to support creative response in the field, which is defined as *an autonomous reaction using available resources to gain the capability to meet key objectives.* The notion of bricolage, producing something from what’s available, by relying on people’s capacity to improvise in the face of uncertainty (Baker et al. 2005) empowers creative reactions under strong pressure. This implicates the possibility of evolutionary system design (Banzhaf 2004) that contains a random combination of entities and is supposed to be realized by a bottom-up approach. In this sense, the frugal IS foundation should support various demands and promote random combinations in the field flexibly.

In summary, theoretical foundation of resilient IS discussed in this paper shown in the following diagram.

Figure 20: Resilient IS design



Since this paper proposes the frugal design for realizing a resilient IS, we should assume network failure and consider alternatives. While the connectivity within communities will have to depend on bricolage, connection to the outside world requires large scale systems that are costly. Building frugal network connecting to outside of the damaged area would be the biggest hurdle for the proposal.

8-2. Implications for practice

Disaster management plans should fit the characteristics of the event that initiates the calamity and the types of outcomes it produces. As new technologies and materials are developed, people adapt new standards; in this sense a system may never be ultimately stable (Orlikowski et al. 2001). However, in a dire situation, people tend to turn to customary patterns for solutions. In view of such observations, a municipal government should make familiar communication channels the foundation of its disaster management plan. As technology advances, government at every level needs to test new technology to be sure it stands up to disasters and helps citizens overcome extreme conditions. An important finding from the Great East Japan Earthquake is that the failure of information and communication technology, including power supply, is unavoidable even though engineers and IS professionals keep on trying to make systems more robust. This leads us to realize that we should focus on strengthening daily-use channels, rather than trying to build a disaster-proof system. However, we can also see different trends in applying technology based on disaster types. Municipalities tend to rely on disaster-proof channels especially immediately after (within 24 hours of) the heavy rain disaster situation. One recommendation will be to take a hybrid approach. This means preparing "dependable" systems (Laprie 1995) that resist interruption, while recognizing the importance of frugal/creative solutions and be ready to use them. This means adapting to new and unfamiliar situations during a disaster means creating conditions promoting the collaboration of people using materials readily available at the time.

A resilient information system requires minimal power resources, familiarity with communication technology and tools, and versatile applications. This paper proposes the following practical guidelines to build a resilient municipal government information system based on IS frugality concepts.

- Prepare disaster resilient and ubiquitously available networks as soon as possible
- Design universal infrastructures to enable combination of other entities
- Instead of government prepared terminals, make use of citizens' own devices that are numerous (Unfamiliar devices especially prepared for disasters were not used)
- Promote public and private sector collaboration for data unison

There is a need for compatibilities at various levels so that various frugal systems (including handwriting) can be integrated to serve the ultimate task of effective and efficient relief. The role of the national government includes supporting the municipal governments to play their critical role by establishing a national disaster recovery infrastructure and standards. It needs to ensure that as soon as possible after a disaster that municipalities have the minimal resources they need for a local response. As the focus is on sustaining life immediately after a disaster, we concentrate on what is required to create an efficient national frugal IS foundation that can be deployed to support effective local relief.

The success of the system is dependent on an individual's comfort and familiarity with devices. People will need to be educated and given the opportunity to practice with the frugal tools in the "peacetime" before a catastrophic event. This testing will allow citizens to understand their responsibilities and will provide load tests of the system's infrastructure.

In addition, since database management skill will be required to the field staff, to provide training opportunities is recommended as a practical implication.

8-3: Limitation and future work

While I have done my best in testing the generalizability of the conclusions, the biggest limitation of this research remains in its external validity. More philosophically, it would be impossible to prove validity of design principles in advance of a future devastating disaster.

At the same time, The Great East Japan Earthquake must have been one of the harshest conditions that human civilization can encounter. If anything can cope with the situation the citizens of the area faced, it is highly likely that it would help in other situations. I hope this research is helpful in converting the experience into design principles.

I persisted in making this research not only analytical but to be design oriented because analyses are only useful to the extent they are adopted in designs of systems. To this goal I adopted DSR that aims at design to create an artifact in order to discover new knowledge in a generative (or creative) mode. The prototype I suggested is probably one of many that are possible.

With such recognition, there is a lot to be done in developing various prototypes. They can take different forms for different purposes. The simplest is a mock-up prototype that models physical aspects of the final system. Another example is an evolutionary prototype which is a modifiable, running model of part of a system (Baskerville et al. 2009).

Another future direction of this research is to breakdown the data model. Since I insist on the importance of the preparedness of a unison database, the detailed structure of the database should be led by future research.

I conclude this thesis with a citation from a paper of Junglas and Watson in 2006 that has motivated me through my Ph.D program.

"The only purpose for building an information system is to meet a human need, and only when we understand the deep structure of these needs will we build better systems."

Every night I made a visit to an area devastatingly damaged by the Great East Japan Earthquake and conducted the interviews to municipalities' officials, I cried because the stories that I heard from them were profoundly sad. I could not even imagine the tragedy they had experienced. For a period after I finished writing the working paper that reported the results of the interviews (appendix 2), I could not bring myself to think further about the earthquake psychologically. However, an encounter one day with the notion of frugal IS urged me to think how the learnings from my study could be utilized for the future. I realized that if we seriously and earnestly tried to understand what happened in the past, however overwhelmingly tragic it might have been, we can extract from the learnings a solution for the future. While the scope of this research is limited to municipalities' disaster relief operations and thus the perfect generalizability should be questioned, I think some of the key concepts that emerged have the potentials to make the world better with IS.

Reference

Alexander, C. 1969. *Notes on the Synthesis of Form*, (Harvard University Press: MA.

Anderies, J. M., Janssen, M. A., and Ostrom, E. 2004. "A framework to analyze the robustness of social-ecological systems from an institutional perspective," *Ecology and Society* (9:1), p [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art18/

Ashenhurst, R. L. 1972. "Curriculum recommendations for graduate professional programs in information systems," *Commun. ACM* (15:5), pp 363-398.

Baker, T., and Nelson, R. E. 2005. "Creating Something from Nothing: Resource Construction through Entrepreneurial Bricolage," *Administrative Science Quarterly* (50:3), pp 329-366.

Banzhaf, W. 2004. "On Evolutionary Design, Embodiment, and Artificial Regulatory Networks," *Embodied Artificial Intelligence* (3139), pp 284-292.

Bartlett, C. A., and Ghoshal, S. 1987. "Managing across Borders: New Strategic Requirements," *Sloan Management Review* (28:4) Summer87, pp 7-17.

Barton, M. A., and Sutcliffe, K. M. 2009. "Overcoming dysfunctional momentum: Organizational safety as a social achievement," *Human Relations* (62:9) September 1, 2009, pp 1327-1356.

Baskerville, R., Pries-Heje, J., and Venable, J. 2009. "Soft design science methodology," in *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology*, ACM: Philadelphia, Pennsylvania, pp. 1-11.

Beck, R., Weber, S., and Gregory, R. 2013. "Theory-generating design science research," *Information Systems Frontiers* (15:4) 2013/09/01, pp 637-651.

Benbasat, I., Goldstein, D. K., and Mead, M. 1987. "The Case Research Strategy in Studies of Information Systems," *MIS Quarterly* (11:3), pp 369-386.

Benbasat, I., and Zmud, R. W. 2003. "THE IDENTITY CRISIS WITHIN THE IS DISCIPLINE: DEFINING AND COMMUNICATING THE DISCIPLINE'S CORE PROPERTIES," *MIS Quarterly* (27:2), pp 183-194.

Berkes, F., Colding, J., and Folke, C. 2003. *Navigating social-ecological systems : building resilience for complexity and change* (Cambridge University Press: Cambridge

Bhamra, R., Dani, S., and Burnard, K. 2011. "Resilience: the concept, a literature review and future directions," *International Journal of Production Research* (49:18), pp 5375-5393.

Bijker, W. E., Hughes, T. P., and Pinch, T. 1987. *The Social Construction of Technological Systems*, (MIT Press: Cambridge, MA.

Bostrom, R. P., and Heinen, J. S. 1977. "MIS Problems and Failures: A Socio-Technical Perspective PART I: THE CAUSES," *MIS Quarterly* (1:3), pp 17-32.

Boulding, K. E. 1956. "GENERAL SYSTEMS THEORY--THE SKELETON OF SCIENCE," *Management Science* (2:3), pp 197-208.

Brohman, M. K., Piccoli, G., Martin, P., Zulkernine, F., Parasuraman, A., and Watson, R. T. 2009. "A Design Theory Approach to Building Strategic Network-Based Customer Service Systems," *Decision Sciences* (40:3), pp 403-430.

Brown, T. 2008. "Design Thinking," *Harvard Business Review* (86:6), pp 84-92.

Butler, B. S., and Gray, P. H. 2006. "RELIABILITY, MINDFULNESS, AND INFORMATION SYSTEMS," *MIS Quarterly* (30:2), pp 211-224.

Cerullo, V., and Cerullo, M. J. 2004. "BUSINESS CONTINUITY PLANNING: A COMPREHENSIVE APPROACH," *Information Systems Management* (21:3) Summer2004, pp 70-78.

Checkland, P., and Scholes, J. 1990. *Soft Systems Methodology in Action*, (Wiley: CA.

Chen, R., Sharman, R., Rao, R., and Upadhyaya, S. Year. "Emergency Response Coordination and IT Support: Contingency and Strategies," Proceedings of the 2007 Americas Conferences on Information Systems, Keystone, CO., 2007.

Ciborra, C. U. 1992. "From thinking to tinkering: The grassroots of strategic information systems," *The Information Society* (8:4) 1992/12/01, pp 297-309.

Comfort, L. K. 1994. "Self-Organization in Complex Systems," *Journal of Public Administration Research and Theory: J-PART* (4:3), pp 393-410.

Comfort, L. K., and Haase, T. W. 2006. "Communication, Coherence, and Collective Action: The Impact of Hurricane Katrina on Communications Infrastructure," *Public Works Management & Policy* (10:4) April 1, 2006, pp 328-343.

Comfort, L. K., Ko, K., and Zagorecki, A. 2004. "Coordination in Rapidly Evolving Disaster Response Systems: The Role of Information," *American Behavioral Scientist* (48:3) November 1, 2004, pp 295-313.

Comfort, L. K., Siciliano, M. D., and Okada, A. 2011. "Resilience, Entropy, and Efficiency in Crisis Management: The January 12, 2010, Haiti Earthquake," *Risk, Hazards & Crisis in Public Policy* (2:3), pp 1-25.

Comfort, L. K., Sungu, Y., Johnson, D., and Dunn, M. 2001. "Complex Systems in Crisis: Anticipation and Resilience in Dynamic Environments," *Journal of Contingencies & Crisis Management* (9:3), p 144.

Communications, M. o. I. A. a. 2011. "Report of the usage of satellite Internet in a disaster situation," Tokyo, Japan.

Davis, G. B., and Olson, M. H. 1985. *Management information systems : conceptual foundations, structure, and development*, (2nd ed.) McGraw-Hill: New York.

Drabek, T. E. 1985. "Managing the Emergency Response," *Public Administration Review* (45:Special), pp 85-92.

Dubin, R. 1969. *Theory building*, (Free Press: NY.

Dutton, J. E., Worline, M. C., Frost, P. J., and Lilius, J. 2006. "Explaining Compassion Organizing," *Administrative Science Quarterly* (51:1), pp 59-96.

Eisenhardt, K. M. 1989. "Building Theories from Case Study Research," *Academy of Management Review* (14:4), pp 532-550.

Eisenhardt, K. M., and Graebner, M. E. 2007. "THEORY BUILDING FROM CASES: OPPORTUNITIES AND CHALLENGES," *Academy of Management Journal* (50:1), pp 25-32.

Fiksel, J. 2003. "Designing Resilient, Sustainable Systems," *Environmental Science & Technology* (37:23) 2003/12/01, pp 5330-5339.

Folke, C. 2006. "Resilience: The emergence of a perspective for social–ecological systems analyses," *Global Environmental Change* (16:3) 8//, pp 253-267.

Gebbie, K. M., and Qureshi, K. 2002. "Emergency and Disaster Preparedness: Core Competencies for Nurses," *The American Journal of Nursing* (102:1), pp 46-51.

Gilbert, C., Eyring, M., and Foster, R. N. 2012. "Two Routes to Resilience," *Harvard Business Review* (90:12), pp 65-73.

Gillespie, D. F., and Streeter, C. L. 1987. "CONCEPTUALIZING AND MEASURING DISASTER PREPAREDNESS," *lnternallonal Journal of Mass Emergencies and Disasters* (5:2), pp 155-176.

Godschalk, D. R., and Brower, D. J. 1985. "Mitigation Strategies and Integrated Emergency Management," *Public Administration Review* (45:Special), pp 64-71.

Gregor, S. 2006. "THE NATURE OF THEORY IN INFORMATION SYSTEMS," *MIS Quarterly* (30:3), pp 611-642.

Gregor, S., and Jones, D. 2007. "The Anatomy of a Design Theory," *Journal of the Association for Information Systems* (8:5), pp 313-335.

Gunderson, L. H. 2001. "Managing surprising ecosystems in southern Florida," *Ecological Economics* (37), pp 371–378.

Hamel, G., and Välikangas, L. 2003. "The Quest for Resilience. (cover story)," *Harvard Business Review* (81:9), pp 52-63.

Hevner, A. R., March, S. T., Park, J., and Ram, S. 2004. "DESIGN SCIENCE IN INFORMATION SYSTEMS RESEARCH," *MIS Quarterly* (28:1), pp 75-105.

Holling, C. S. 1973. "Resilience and Stability of Ecological Systems," *Annual Review of Ecology and Systematics* (4:1), pp 1-23.

Hollnagel, E., Woods, D. D., and Leveson, N. 2006. *Resilience Engineering: Concepts And Precepts*, (Ashgate Pub Co.: Burlington, VT.

Horne, J. F., and Orr, J. E. 1998. "Assessing behaviors that create resilient organizations," *Employment Relations Today* (24:4), pp 29-39.

Jick, T. D. 1979. "Mixing Qualitative and Quantitative Methods: Triangulation in Action," *Administrative Science Quarterly* (24:4), pp 602-611.

Juergens, H. F. 1977. "Attributes of Information System Development," *MIS Quarterly* (1:2), pp 31-41.

Junglas, I., and Ives, B. 2007. "RECOVERING IT IN A DISASTER: LESSONS FROM HURRICANE KATRINA," *MIS Quarterly Executive* (6:1), pp 39-51.

Junglas, I. A., and Watson, R. T. 2006. "THE U-CONSTRUCTS: FOUR INFORMATION DRIVES," *Communications of the Association for Information Systems* (17), pp 2-43.

Kanter, R. M. 2006. "Innovation: The Classic Traps. (cover story)," *Harvard Business Review* (84:11), pp 72-83.

Kataoka, K., Uehara, K., and Murai, J. 2009. "LifeLine Station: a quickly deployable package for post disaster communications," Proceesings in Internet conference 2009, pp 41-47.

Kauffman, S. A. 1993. *The Origins of Order: Self-Organization and Selection in Evolution*, (Oxford University Press: U.S.A.

Klein, H. K., and Myers, M. D. 1999. "A SET OF PRINCIPLES FOR CONDUCTING AND EVALUATING INTERPRETIVE FIELD STUDIES IN INFORMATION SYSTEMS," *MIS Quarterly* (23:1), pp 67-93.

Kuechler, B., and Vaishnavi, V. 2008. "On theory development in design science research: anatomy of a research project," *European Journal of Inform Systems* (17:5) //print, pp 489-504.

Kuhn, T. S. 2012. *The structure of scientific revolutions*, (4th ed.) University of Chicago Press: Chicago.

Kunreuther, H., and Miller, L. 1985. "Insurance versus Disaster Relief: An Analysis of Interactive Modelling for Disaster Policy Planning," *Public Administration Review* (45:Special), pp 147-154.

La Porte, T. R. 1996. "High Reliability Organizations: Unlikely, Demanding and At Risk," *Journal of Contingencies & Crisis Management* (4:2), pp 60-71.

La Porte, T. R., and Consolini, P. M. 1991. "Working in Practice but Not in Theory: Theoretical Challenges of "High-Reliability Organizations"," *Journal of Public Administration Research and Theory: J-PART* (1:1), pp 19-48.

Lee, A. S., and Baskerville, R. L. 2003. "Generalizing Generalizability in Information Systems Research," *Information Systems Research* (14:3), pp 221-243.

Lee, H. L. 2004. "THE TRIPLE-A Supply Chain," *Harvard Business Review* (82:10), pp 102-112.

March, S. T., and Smith, G. F. 1995. "Design and natural science research on information technology," *Decision Support Systems* (15:4) 12//, pp 251-266.

Markus, M. L., Majchrzak, A., and Gasser, L. 2002. "A DESIGN THEORY FOR SYSTEMS THAT SUPPORT EMERGENT KNOWLEDGE PROCESSES," *MIS Quarterly* (26:3), pp 179-212.

Mase, K. 2011. "How to deliver your message from/to a disaster area," *Communications Magazine, IEEE* (49:1), pp 52-57.

McLoughlin, D. 1985. "A Framework for Integrated Emergency Management," *Public Administration Review* (45:Special), pp 165-172.

Mintzberg, H. 1979. "An Emerging Strategy of "Direct" Research," Administrative Science Quarterly (available at http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=3980555&lang=ja&site=ehost-live).

Mintzberg, H., and Waters, J. A. 1985. "Of Strategies, Deliberate and Emergent," *Strategic Management Journal* (6:3), pp 257-272.

Mumford, E. 2003. "Information Systems Research and the Quest for Certainty," *Journal of the Association for Information Systems* (4), pp 197-205.

Myers, M. D. 1997. "Qualitative Research in Information Systems," *MIS Quarterly* (21:2), pp 241-242.

Ng, B.-Y., and Kankanhalli, A. 2012. "Information Systems for Large-Scale Event Management: A Case Study," *Pacific Asia Journal of the Association for Information Systems* (4:3), pp 15-44.

O'Toole, J., Galbraith, J., and Lawler Iii, E. E. 2002. "When Two (or More) Heads are Better than One: THE PROMISE AND PITFALLS OF SHARED LEADERSHIP," *California Management Review* (44:4) Summer2002, pp 65-83.

Orlikowski, W. J. 1991. "Integrated information environment or matrix of control? The contradictory implications of information technology," *Accounting, Management and Information Technologies* (1:1) //, pp 9-42.

Orlikowski, W. J. 1992. "THE DUALITY OF TECHNOLOGY: RETHINKING THE CONCEPT OF TECHNOLOGY IN ORGANIZATIONS," *Organization Science* (3:3), pp 398-427.

Orlikowski, W. J., and Baroudi, J. J. 1991. "Studying Information Technology in Organizations: Research Approaches and Assumptions," *Information Systems Research* (2:1), pp 1-28.

Orlikowski, W. J., and Gash, D. C. 1994. "Technological frames: making sense of information technology in organizations," *ACM Trans. Inf. Syst.* (12:2), pp 174-207.

Orlikowski, W. J., and Lacono, C. S. 2001. "Research Commentary: Desperately Seeking the 'IT' in IT Research--A Call to Theorizing the IT Artifact," *Information Systems Research* (12:2), pp 121-134.

Pearson, C. M., and Mitroff, I. I. 1993. "From crisis prone to crisis prepared: a framework for crisis management," *Executive (19389779)* (7:1), pp 48-59.

Peffers, K. E. N., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. 2007. "A Design Science Research Methodology for Information Systems Research," *Journal of Management Information Systems* (24:3) Winter2007/2008, pp 45-77.

Perrow, C. 1967. "A Framework for the Comparative Analysis of Organizations," *American Sociological Review* (32:2), pp 194-208.

Perrow, C. 1983. "The Organizational Context of Human Factors Engineering," *Administrative Science Quarterly* (28:4), pp 521-541.

Perrow, C. 1984. *Normal accidents: Living with high-risk technologies*, (Basic Books: NY.

Pimm, S. L. 1991. *The balance of nature? : ecological issues in the conservation of species and communities*, (University of Chicago Press: Chicago.

Pokharel, M., Seulki, L., and Jong Sou, P. Year. "Disaster Recovery for System Architecture Using Cloud Computing," Applications and the Internet (SAINT), 2010 10th IEEE/IPSJ International Symposium on2010, pp. 304-307.

Ponomarov, S. Y., and Holcomb, M. C. 2009. "Understanding the concept of supply chain resilience," *International Journal of Logistics Management* (20:1), pp 124-143.

Popper, K. 2002. *The Logic of Scientific Discovery*, (Routledge: NY.

Post, G. V., and Diltz, J. D. 1986. "A Stochastic Dominance Approach to Risk Analysis of Computer Systems," *MIS Quarterly* (10:4), pp 363-375.

Prehofer, C., and Bettstetter, C. 2005. "Self-organization in communication networks: principles and design paradigms," *Communications Magazine, IEEE* (43:7), pp 78-85.

Procopio, C. H., and Procopio, S. T. 2007. "Do You Know What It Means to Miss New Orleans? Internet Communication, Geographic Community, and Social Capital in Crisis," *Journal of Applied Communication Research* (35:1), pp 67-87.

Quarumcll i, E.L. 1981. "Disaster Planning: Small and Lurge • Past, Present, and Future," in Proceedings: Americtm Red Crrus EFO Division DisQSter Conference, pp. 1-26. Alexandria, VA

Reddy, M. C., Paul, S. A., Abraham, J., McNeese, M., DeFlitch, C., and Yen, J. 2009. "Challenges to effective crisis management: Using information and communication technologies to coordinate emergency medical services and emergency department teams," *International Journal of Medical Informatics* (78:4) 4//, pp 259-269.

Rivard, S. 2014. "The Ions of Theory Construction," MIS Quarterly & The Society for Information Management (available at http://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=95754049&lang=ja&site=ehost-live).

Robertazzi, T. G., and Sarachik, P. 1986. "Self-organizing communication networks," *Communications Magazine, IEEE* (24:1), pp 28-33.

Roberts, K. H., Stout, S. K., and Halpern, J. J. 1994. "Decision Dynamics in Two High Reliability Military Organizations," *Management Science* (40:5), pp 614-624.

Rochilin, G. 1993. "Defining High Reliability Organizations in Practice: A Taxonomic Prologue," in *New Challenges to understanding Organizations*, K. H. Roberts (ed.), Macmillan: NY, pp. 11-32.

Sakurai, M., and Kokuryo, J. 2012. "Municipal Government ICT in 3.11 Crisis: Lessons from the Great East Japan Earthquake and Tsunami Crisis," Berkman Center for Internet & Society, Cambridge, MA.

Sakurai, M., and Kokuryo, J. 2013. "Preparing for Creative Responses to "Beyond Assumed Level" Disasters: Lessons from the ICT Management in the 2011 Great East Japan Earthquake Crisis," *Corporate Ownership & Control* (10:2), pp 195-206.

Sakurai, M., Watson, R. T., Abraham, C., and Kokuryo, J. 2014. "Sustaining life during the early stages of disaster relief with a frugal information system: learning from the great east Japan earthquake," *Communications Magazine, IEEE* (52:1), pp 176-185.

Settle, A. K. 1985. "Financing Disaster Mitigation, Preparedness, Response, and Recovery," *Public Administration Review* (45:Special), pp 101-106.

Seville, E., Brunsdon, D., Dantas, A., Masurier, J. L., Wilkinson, S., and Vargo, J. 2006. "Building organisational resilience: a summary of key research findings," in *Resilient Organisations Research Programme*: New Zealand.

Shklovski, I., Palen, L., and Sutton, J. 2008. "Finding community through information and communication technology in disaster response," in *Proceedings of the 2008 ACM conference on Computer supported cooperative work*, ACM: San Diego, CA, USA, pp. 127-136.

Shoaf, K. I., and Rottman, S. J. 2000. "The Role of Public Health in Disaster Preparedness, Mitigation, Response, and Recovery," *Prehospital and Disaster Medicine* (15:04), pp 18-20.

Simmons, S. C., Murphy, T. A., Blanaovich, A., Workman, F. T., and et al. 2003. "Telehealth technologies and applications for terrorism response: A report of the 2002 coastal North Carolina domestic preparedness training exercise," *Journal of the American Medical Informatics Association* (10:2), pp 166-176.

Simon, H. A. 1996. *The Sciences of the Artificial* (third ed.) MIT Press: MA.

Smit, B., and Wandel, J. 2006. "Adaptation, adaptive capacity and vulnerability," *Global Environmental Change* (16:3) 8//, pp 282-292.

Smith, H. A., Watson, R. T., and Sullivan, P. 2012. "DELIVERING AN EFFECTIVE ENTERPRISE ARCHITECTURE AT CHUBB INSURANCE," *MIS Quarterly Executive* (11:2), pp 75-82.

Starbird, K., and Palen, L. 2011. ""Voluntweeters": self-organizing by digital volunteers in times of crisis," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM: Vancouver, BC, Canada, pp. 1071-1080.

Suzuki, H., Kaneko, Y., Mase, K., Yamazaki, S., and Makino, H. Year. "An Ad Hoc Network in the Sky, SKYMESH, for Large-Scale Disaster Recovery," Vehicular Technology Conference, 2006. VTC-2006 Fall. 2006 IEEE 64th2006, pp. 1-5.

Takeuchi, Y., Nakamura, T., Tamura, H., Kagawa, K., and Takahashi, K. Year. "The proposal of geographically distributed OSS against a great earthquake — A study on macroscale disaster recovery," Network Operations and Management Symposium (APNOMS), 2011 13th Asia-Pacific2011, pp. 1-8.

Team, S. o. t. G. E. J. E. i. C. T. S. 2011. "Great East Japan Earthquake Information & Communication Technology Support Team Activity Report," Tokyo, Japan.

Union, I. T. 2013. "The World in 2013: ICT Facts and figures," Geneva, Switzerland.

Walls, J. G., Widmeyer, G. R., and El Sawy, O. A. 1992. "Building an Information System Design Theory for Vigilant EIS," *Information Systems Research* (3:1), pp 36-59.

Watson, R. T. 2014. "A Personal Perspective on a Conceptual Foundation for Information Systems," *Journal of the Association for Information Systems* (15:8), pp 514-535.

Watson, R. T., Kunene, K. N., and Islam, M. S. 2013. "Frugal information systems (IS)," *Information Technology for Development* (19:2), pp 176-187.

Watson, R. T., Pitt, L. F., Berthon, P., and Zinkhan, G. M. 2002. "U-Commerce: Expanding the Universe of Marketing," *Journal of the Academy of Marketing Science* (30:4) Fall2002, pp 333-347.

Weick, K. E. 1979. *Social Psychology of Organizing*, (2nd ed.) Addison-Wesley: MA.

Weick, K. E. 1993. "The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster," *Administrative Science Quarterly* (38:4), pp 628-652.

Weick, K. E., and Sutcliffe, K. M. 2001. *Managing the Unexpected*, (Jossey-Bass: CA.

Weick, K. E., and Sutcliffe, K. M. 2006. "Mindfulness and the Quality of Organizational Attention," *Organization Science* (17:4), pp 514-524.

Weick, K. E., Sutcliffe, K. M., and Obstfeld, D. 1999. "Organizing for high reliability: Processes of collective mindfulness," *Research in Organizational Behavior* (21), pp 81-123.

Yin, R. K. 2008. *Case Study Research*, (4th ed.) SAGE: CA.

Zolli, A., and Healy, A. M. 2012. *Resilience: Why Things Bounce Back*, (Free Press: City of New York, NY.

Appendix-1

Questionnaire for interviews to municipalities on the Great East Japan Earthquake

1. Basic information on interviewed municipalities

① Geographical features, populations, the gross area, the number of officials, organizations and financial situation

② Damage level (the Richter scale and the number of death, missing, and destroyed building)

③ Structure of municipality office building, earthquake-resistant construction

④ Situations when the earthquake happened (based on chronological sequence)

2. Operations of ICT divisions

① Organizational and command systems

② Disaster relief operations

③ Contracts with vendors in assuming a disaster situation

④ Status of data back-up (location/frequency/method)

⑤ Status of installation of National disaster victim support system

3. Situations of ICT division when the earthquake happened

① Immediately after the earthquake

② Damage situations and recovery process of information systems

③ Damage situations and recovery process of power supply and network connectivity

④ Damage situations and recovery process of hardware

⑤ Damage situations and recovery process of facilities

4. Opinions for handling future disaster situations

① How to secure power supply and communications in emergency situations?

② How to realize redundancy of network connectivity?

③ How to do data back-up?

④ How to draw up a BCP?

⑤ How to think about the usage of cloud computing with other municipalities?

⑥ Demands for the National government and prefectural governments

Appendix-2

Working paper of the interviews to municipalities on the Great East Japan Earthquake

Research Publication No. 2012-14
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Municipal Government ICT in 3.11 Crisis: Lessons from the Great East Japan Earthquake and Tsunami Crisis

Mihoko Sakurai
Jiro Kokuryo

Translated, abridged and revised from original report prepared for Local Authorities Systems Development Center.

This working paper is being released by the Berkman Center for Internet & Society in partnership with Keio University.

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Working Paper

Municipal Government ICT in 3.11 Crisis:

Lessons from the Great East Japan Earthquake and Tsunami Crisis

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Keio University, March 2012

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Translated, abridged and revised from original report prepared for Local Authorities Systems Development Center

Municipal Government ICT in 3.11 Crisis:

Lessons from the Great East Japan Earthquake and Tsunami Crisis

By Mihoko Sakurai and Jiro Kokuryo

Keio University

Abstract

A structured field surveys of ICT divisions in 13 municipalities in areas devastated by the Great East Japan Earthquake and Tsunami on March 11, 2011 revealed 1) lack of ICT business continuity plans (BCP), 2) importance (and lack of) comprehensive data backup policy, 3) necessity to deal with diverse situations, 4) importance of organizing collaborative network among governments and private sectors, 5) importance of securing power and network supply among many other observations. Recommendations are made based on the findings on how to formulate BCP that can deal with diverse range of situations, and policies in creating collaborative network of diverse range of organizations to protect vital information infrastructure in crisis. Strong interests were shown toward the use of cloud technologies for future backup purposes.

Special note

In the course of conducting this survey, we met with numerous municipal government employees. Many of them, despite being victims themselves, worked tirelessly to resume operation of resident service counters. Others were forced to work under horrifying work conditions in areas where the tsunami had washed away everything in its path. Employees of municipal governments in Fukushima Prefecture, whose lives were uprooted by the nuclear accident and who had to leave their hometowns for indefinite periods of time, worked together diligently to support local residents.

We must not assume that they have quietly resigned themselves to the harsh reality they experienced. They possess immense mental and emotional strength to look adversity in the face and carry on their duties with a strong sense of commitment, despite knowing that they may never receive any recognition or praise for their efforts. We were greatly impressed by them and their strength served as the driving force behind this report.

41 employees of municipality and prefectural governments affected by the disaster participated in this survey. We would like to express our sincere gratitude and respect to each one of them for their cooperation in a difficult situation.

1. Introduction

This report analyses and summarizes the results of field surveys conducted at the Information and Communications Technology (ICT) divisions of 13 municipalities in Iwate, Miyagi and Fukushima Prefectures that were devastated by the Great East Japan Earthquake and Tsunami on March 11, 2011. The survey covered damages caused and the status of recovery, as well as opinions on measures that must be implemented in the future.

The analysis and summary was carried out with the following three objectives:

1) To document the action taken by the ICT divisions during the disaster

2) To organize support requests manifested during the survey from the officials of municipal governments of the affected areas to the central governments

3) To prompt discussion regarding the future action that must be taken by the ICT divisions of municipal governments

Key observations from the research can be summarized as follows:

(1) <u>ICT BCP (business continuity plan) did not exist prior to disaster</u>

Although each prefectural government had created regional disaster response plans, none of the ICT divisions at each of the municipalities had drawn up a business continuity plan (BCP), and emergency responses were mostly left to the discretion of each affected site. As described in (2) below, taking into consideration the different situations that could ensue a major disaster, it may be necessary to create a flexible emergency response plan for the future that assumes various possibilities, rather than a stereotypical one that envisages only one situation.

(2) Diverse situations among locations existed, requiring non-uniform measures

The expectations of ICT divisions and the requisites for and processes towards recovery varied greatly depending on several factors, including structural damage to government facilities and server rooms, loss of data, whether power supply and network connectivity could be resumed immediately, whether communication tools such as cell phones remained functional; and the degree of mass emergency evacuation to locations outside the affected area.

(3)There were temporal shifts in expectations towards ICT functions requiring timely measures

Immediate response measures in the municipalities that experienced major devastation focused on saving lives and guiding survivors to evacuation centers, and in some areas little priority was given to reopening resident service counters (there was however a sense of urgency regarding the need for access to residents' personal information in order to facilitate rescue operations). Some ICT divisions even dispatched employees to do relief work with just skeleton staff remaining at the office. At these municipalities, as well, providing support to the affected people at various post-disaster stages was difficult without the use of information and communication technologies (ICT). It became more evident than ever that post-disaster expectations toward ICT divisions change as time passes.

(4)Difference existed in the preparation levels for earthquake and tsunami

Excluding destruction caused by the tsunami and damage to communication cables, most of the ICT divisions did not suffer any physical damage to equipment as a direct result of the earthquake, such as due to the collapse of buildings. We assume this is because in the past ten years many municipal government office buildings had implemented quake-proofing measures, including earthquake-resistance tests and reinforcement of structures.

In prefectures close to the seacoast, however, some government offices with servers and other data storage facilities located on the lower floors of the building lost a considerable amount of digital data, and we assume there was no standard policy in place regarding tsunami countermeasures.

(5)Private sector played a major role in the recovery process outside of contracts

Although most of the agreements entered into with subcontractors of information processing systems included no clauses regarding action to be taken in the event of a disaster, they proactively undertook different operations that were beyond the scope of their contracts, thus contributing greatly to recovery efforts. Some companies even had backup files stored at their facilities that enabled lost digital data to be recovered.

(6) Critical issues exist in the handling of digital data at government offices

The importance of creating backup files has been emphasized from the perspective of business continuity planning by ICT divisions as well. In reality, however, the management of application software and electronic data was mostly entrusted to individual business divisions and not only were there no standard guidelines regarding data backup, in some government offices the relevant ICT division was not aware of what kind of data was being stored and the storage methods being used.

This is also indicative of issues in the system. For example, in government offices where external storage of data was prohibited to prevent leakage of personal information, it was impossible to recover valuable information that was lost in the tsunami.

Unlike damage to hardware and application software that can be fixed, restoration of lost electronic data is difficult, hampering the entire recovery process. It is necessary to raise awareness of digital data as a prime asset that must be protected in the event of a disaster.

(7) Critical importance of ensuring stable power supply and uninterrupted lines of communication to key infrastructure

Although the intensity of damage suffered by each organization was different, most municipalities stressed the importance of ensuring stable power supply even during a disaster. This need was further highlighted by the fact that in many instances ICT services could not be provided to residents because of disrupted power supply, despite no damage to equipment.

Further, with regard to telecommunications lines linking branch offices and other local offices, many municipalities with independently installed cables had to investigate damages themselves, therefore it took them a significant amount of time to restore communication. This brings to light the limitations municipalities face in laying and maintaining telecommunication lines on their own and underlines the need for establishing relevant infrastructure that is not restricted by the administrative framework of the local municipality.

(8) Little utilization of the Disaster Victims Support System[*]

Disaster Victims Support System, a government endorsed comprehensive post disaster support system which was developed after 1995 Hanshin Awaji Earthquake that killed thousands, was not utilized as expected. Instead, municipal governments opted to use simpler software such as Microsoft Excel or quickly modifying original software to suit requirements. The reason for the less than expected use of the package was lack of time to learn how to operate the software package in the disaster situation. It is notable that much ICT resources were spent in the most critical moments developing systems that meet the demands of the diverse local situations.

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[*] A system developed by Nishinomiya City, Hyogo Prefecture after the Great Hanshin earthquake, designed to provide comprehensive support to municipal governments in the event of an earthquake, typhoon or other natural disaster. In 2005, the system program was registered in the Local Authorities Systems Development Center (LASDEC) program library for municipal government operations and is provided free of charge to municipal governments throughout Japan.

(9) Keen interest exist in adopting cloud computing as future preparation

With regard to the use of cloud computing as one measure to protect digital files in the future, employees of ICT divisions showed keen interest in the technology especially as a means of backing up data. Many of them, however, expressed concern over security issues.

Opinions are divided as to the use of the Local Government Wide Area Network (LGWAN)* between those who favor its utilization for data backup and others who consider it impractical to use the system at its current connection speed. To deal with this issue, measures were taken in the Third LGWAN Maintenance Plan to increase the connection speed of the backbone line. It is anticipated that prefectural governments will be able to access the LGWAN faster when the improved backbone line becomes operational in April 2012.

Despite the keen interest shown by ICT divisions in the shared use of computer networks, including cloud computing, issues such as standardization of data formats still remain and it is necessary to adopt a top-down approach towards implementing consistent measures for standardization.

* The Local Government Wide Area Network (LGWAN) is an administration-focused mutual network of local public bodies that was established in order to facilitate highly efficient data utilization through streamlined exchange and sharing of data. LGWAN is reciprocally linked to the central government ministries' Kasumigaseki WAN for information exchange with national administrative organs. LGWAN is highly secure and uses ASP to make available a variety of administrative applications.

2. Survey conducted

Visits were made to 13 municipal governments and 3 prefectural governments. Survey participants were interviewed for approximately two hours. Much effort was put in to collect comparable factual data among the locations.

The survey topics may be broadly divided into the following:

1) The role of the ICT division;

2) Damage caused to the ICT division on March 11 and the steps taken toward recovery; and

3) Thinking on future action after experiencing the disaster and recovery thereafter

With regards to 2), participants were asked questions about the damage caused and the recovery measures that were taken with regard to four information processing systems (basic resident registration, family registration, tax and social security), power supply and transmission lines related infrastructure, computer hardware, and facilities.

Table 1: Municipalities surveyed and survey date

Municipality

Municipalities surveyed		Departments visited*	Survey date
Iwate Prefecture	Miyako City	Administration Planning Dep., Planning Div., Information Processing Promotion Office	December 16 (Fri), 2011
	Rikuzentakata City	Planning Dep. Collaboration Promotion Office., Administration Dep., Administration Div. (telephone interviews)	November 29 (Tue), 2011
	Kamaishi City	Administration Planning Dep., Public Affairs Division, Information Processing Promotion Section	December 15 (Thu), 2011
	Otsuchi Town	Disaster Recovery Bureau, Recovery Measures Promotion Office and Disaster Recovery Bureau, Information Processing Promotion Office Note: The survey also covered employees from the Finances and Planning Division, Yahaba Town, Iwate Prefecture, who were sent for relief work.	December 15 (Thu), 2011, January 19 (Thu) and January 20 (Fri), 2012
Miyagi Prefecture	Sendai City	Administration Planning Bureau, Information Policy Department, Information Policy Division	December 22 (Thu), 2011
	Ishinomaki City	Planning Department, Information Policy Division	November 25 (Fri), 2011
	Kesennuma City	Planning Department, Planning Policy Division, Information Processing Promotion Office	November 29 (Tue), 2011
	Higashimatsushima City	Disaster Recovery Policy Department, Recovery Policy Division, Information Processing Promotion Unit	November 25 (Fri), 2011
	Minamisanriku Town	Disaster Recovery Planning Division, Information Processing Promotion Section	January 20 (Fri), 2012
Fukushima Prefecture	Iwaki City	Administration Department, Information Policy Division	December 22 (Thu), 2011
	Minamisoma City	Administration Planning Department, Information Policy Division	December 13 (Tue), 2011
	Futaba Town	Saitama Branch, Residents Lifestyle Improvement Division and Administration Division	January 12 (Thu), 2012
	Namie Town	Nihonmatsu Office Administration Unit	December 9 (Fri), 2011

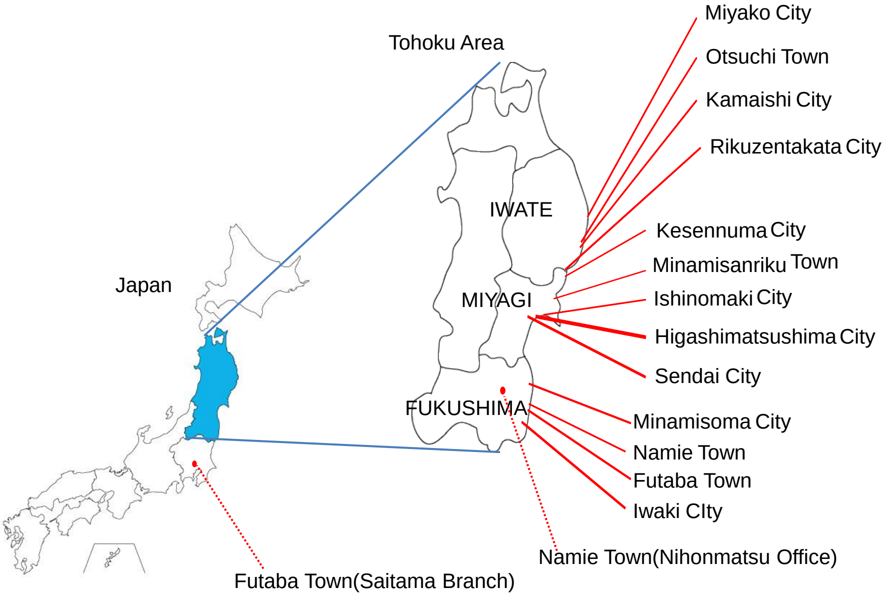
* Names of organizations are as at the time of the survey

Prefecture

Municipalities surveyed	Departments visited*	Survey date
Iwate Prefecture	Regional Policies Department, Regional Development and Promotion Office, Regional Information Processing In-charge Regional Policies Department, Municipality Division Administrative Department, Legal Affairs Division, Administrative Information Processing In-charge	February 16 (Thu), 2012
Miyagi Prefecture	Disaster Recovery and Planning Department, Information Policy Division	February 20 (Mon), 2012
Fukushima Prefecture	Planning Department, Information Systems Division	February 20 (Mon), 2012

* Names of organizations are as at the time of the survey

Figure 1: Municipalities visited



3. Overview of events that took place in the ICT divisions of municipal governments affected by the Great East Japan Earthquake

In general, regional disaster response plans drawn up by each municipality specify the scope of action to be taken by the relevant organization during a disaster, such as setting up disaster response headquarters and confirming the safety of residents. Some plans also clarify the role of each operational division in the event of a disaster.

With regard to ICT divisions, however, none of the 13 municipalities surveyed had drawn up action plans that included business continuity planning, and responses by the respective ICT divisions at the time of the disaster were mainly based on their own discretion. After the disaster response headquarters were started up, many of the municipalities dispatched personnel for tasks such as operating evacuation centers and transporting goods under instructions from those headquarters. Further, although several of the regional disaster response plans stipulated that the role of the ICT divisions during a disaster would be information services for the residents; this was not possible because key communication means were disrupted.

The following is a typical timeline of responses, created based on activities conducted by employees of ICT divisions at the municipalities that were surveyed, in the months that immediately followed the disaster on March 11.

1) Immediately after disaster struck, checked the condition of the servers and other equipment in the server room.

2) Confirmed resident whereabouts, and helped with transporting goods and other tasks related to the operation of evacuation centers.

3) After power supply was resumed, worked on restoring information processing systems, networks and other related equipment within the facility.

4) Studied the introduction of and developed information processing systems that can be used for disaster response activities.

5) Worked to restore public data networks in the region.

Subcontractors of information processing systems and employees from other prefectural governments contributed immensely to realizing (3), (4) and (5) above. Private businesses, other than subcontractors of information processing systems, also supported relief efforts significantly through the provision of office automation and other equipment necessary to conduct work.

Five of the municipalities surveyed had to relocate all government functions, making it difficult to conduct an integrated assessment of recovery processes. In this section, however, we have tried to describe in an organized manner the damage caused and steps taken towards recovery in five areas vital to maintaining ICT environments: power supply, telecommunications infrastructure, information processing systems (digital data and servers), business relations with subcontractors of information processing systems, and facilities (including computer hardware).

In order to provide an overview of the status of devastation at the municipalities surveyed, prior to analysis of the situation in each area, we have summarized in the table 2 below information regarding the damage to each municipal government office building, relocation of resident service counters, damage to the relevant ICT division employees, loss of digital data/use of backup data, and earthquake resistance reinforcement measures taken over the past ten years.

From this information, it is apparent that the definitive effects of the tsunami, and not the earthquake, made it impossible to continue operations at all 13 municipal government office buildings. It is our thinking that the quake resistance testing and proofing measures implemented by many of the municipalities over the period of the past ten years paid off.

Table 2: Damages suffered by the municipal government offices surveyed and relocation of resident service counters

(As of January 2012)

Municipalities surveyed		Damage to the government office building	Relocation of resident service functions	Damage to the ICT division employees	Loss of digital data/ use of backup data*	Earthquake resistance reinforcement measures taken over the past ten years
Iwate Prefecture	Miyako City	First floor submerged	No	No damage	No loss/backup data not used	Not implemented Diagnosed as requiring reinforcement
	Rikuzentakata City	Totally submerged (3-storied building)	Yes	Damaged	Data lost/recovered from server hard disk drive and data stored at information processing systems subcontractors' facilities	Implemented in fiscal 2002
	Kamaishi City	Buildings 1 – 4 partially submerged	Yes	No damage	No loss/backup data not used	Not implemented Diagnosed as requiring reinforcement
	Otsuchi Town	Totally submerged (2-storied building	Yes	Damaged	Data lost/recovered from server hard disk drive and data stored at information processing systems subcontractors' facilities	Not implemented
Miyagi Prefecture	Sendai City	No flooding	No	No damage	No loss/backup data not used	Implemented in fiscal 2009
	Ishinomaki City	No flooding	No	No damage	No loss/some backup data used	Earthquake resistance test completed
	Kesennuma City	First floor of branch	Yes Partially	No damage	No loss/backup data not used	Not implemented

		office submerged	damaged			
	Higashimatsushima City	No flooding	No	No damage	No loss/backup data not used	Implemented in fiscal 2004
	Minamisanriku Town	3-storied building washed away	Yes	Damaged	Data lost/recovered from data stored at information processing systems subcontractors' facilities	Details not available
Fukushima Prefecture	Iwaki City	First story floor partially destroyed	No	No damage	No loss/backup data not used	Not implemented Plans currently being drafted for earthquake proofing
	Minamisoma City	No flooding	No	No damage	No loss/backup data not used	Implemented in fiscal 2006
	Futaba Town	No flooding	Yes	No damage	No loss/backup data used	Not implemented
	Namie Town	No flooding	Yes	No damage	No loss/backup data used	15-year old building

*Data on the system network under the ICT division supervision

As of January 2012, governments of five municipalities, Rikuzentakata City, Otsuchi Town, Minamisanriku Town, Futaba Town and Namie Town, were operating at makeshift offices. Three of the government offices had to be relocated because the original buildings were submerged by the tsunami floodwaters, and two due to the nuclear accident at the Fukushima Daiichi nuclear power station (hereinafter referred to as the 'nuclear accident') operated by Tokyo Electric Power Company. In Kamaishi City, only resident service counters were moved to another location within city limits because Building 1 of the municipal government office, where resident service functions were earlier carried out, was destroyed by the tsunami and power supply in the area could not be restored immediately. Further, due to land subsidence and heaps of rubble in the vicinity, the area was deemed unsafe.

In Rikuzentakata City, Otsuchi Town and Minamisanriku Town, temporary office buildings were constructed close to the original locations and operations resumed there between March and April. In Futaba Town and Namie Town, the offices had to be relocated twice before operations were resumed at the current location (as of January 2012) and plans call for further moves or transfers to yet unspecified locations. (see Table 3).

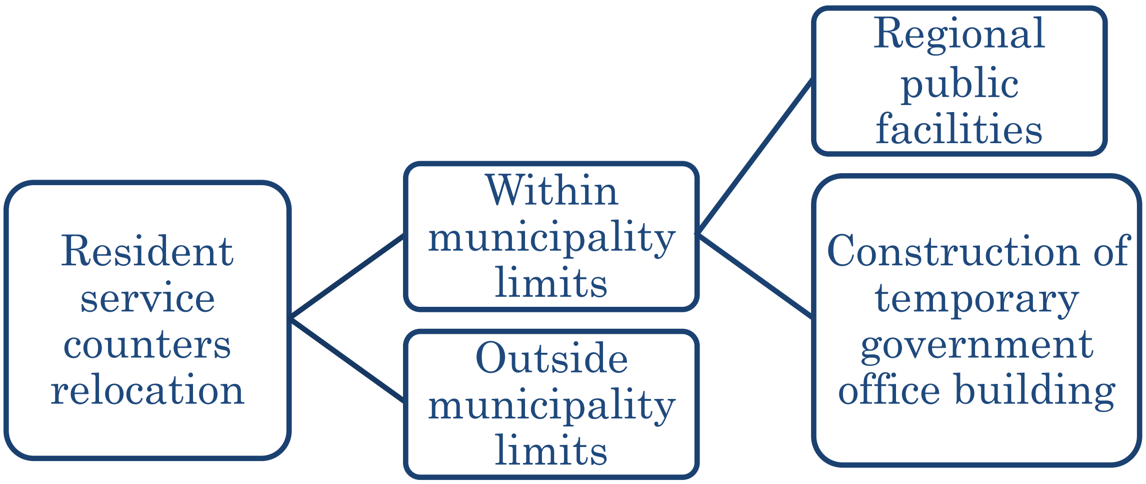
Table 3: Relocation of resident service counters

(As of February 2012)

Municipalities surveyed		Damage to the government office building	Relocation of resident service counters
Iwate Prefecture	Rikuzentakata City	Submerged	Makeshift office set up in a prefabricated house on March 19 and services resumed on May 16. Following Buildings 1 and 2, temporary office Building 3 completed on July 18, and Building 4 under construction as of February 2012.
	Kamaishi City	Buildings 1 - 4 partially submerged	Operations resumed at the Kamaishi City Education Center on April 1, and from April 18 at Sea Plaza Kamaishi (near JR Kamaishi Stn.) following relocation.
	Otsuchi Town	Submerged	Services resumed on April 13 at the Central Community Hall, and were moved to a temporary office at the Otsuchi Elementary School ground from April 25, which is currently being expanded.
Miyagi Prefecture	Minamisanriku Town	Washed away by the tsunami	Temporary office established on March 22. A total of 16 buildings completed by October.
Fukushima Prefecture	Futaba Town	No damage	Evacuated to Kawamata Town, Fukushima Prefecture, on March 12; moved to Saitama Super Arena (Saitama City, Saitama Prefecture) on the 19 of the same month; and then again on the 31 to the now defunct Saitama Prefectural Kisai High School (Kazo City, Saitama Prefecture), where operations were resumed.
	Namie Town	No damage	Evacuated to the Namie Town, Tsushima branch office on March 12, relocated on the 15 to Towa Area, Nihonmatsu City of Fukushima Prefecture. From May 23, operations were resumed at an office within the Fukushima Gender Equality Centre in Nihonmatsu City.

Shown below is a diagrammatic representation of resident service counters relocation at the above six municipalities.

Figure 2: Diagrammatic representation of resident service counters relocation



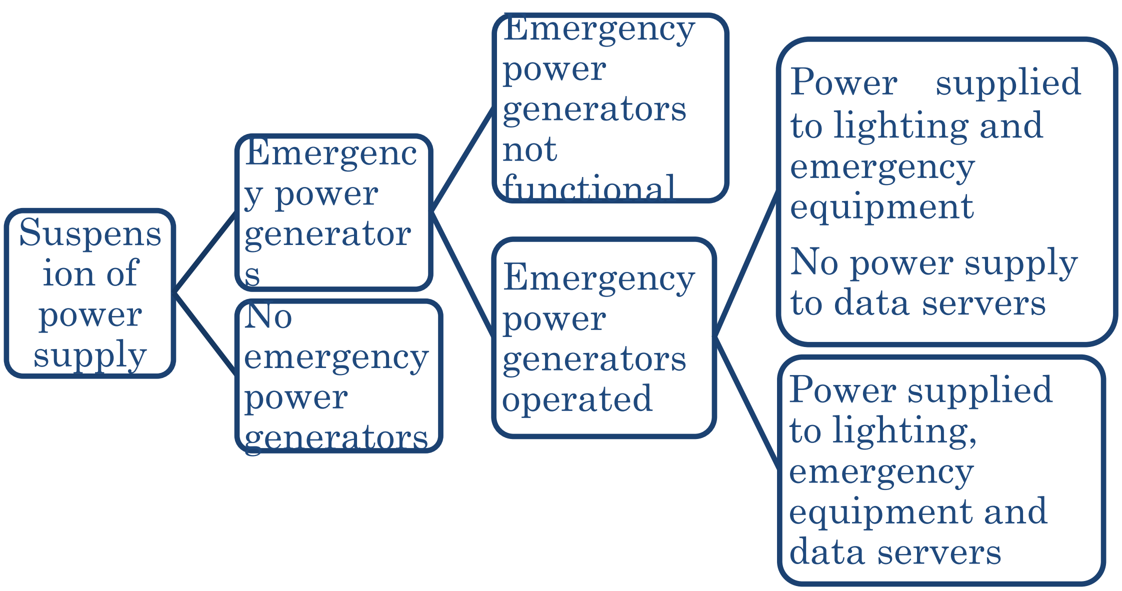
The following sections provide a summary of the damage caused and steps taken towards recovery in five areas vital to maintaining ICT work environments: power supply, telecommunications infrastructure, information processing systems (digital data and servers), business relations with subcontractors of information processing systems, and facilities (including hardware).

4. Power supply

Broadly speaking, potential problems that ICT divisions face in the wake of a disaster are 1) relocation of the server room, the operations room and other facilities, 2) suspension of power supply, 3) disruption of telecommunications lines or damage to information processing systems. Suspension of power supply affected business continuity the most at the 13 municipalities that were surveyed.

Excluding Iwaki City, Minamisoma City and Futaba Town, power supply was suspended at ten of the 13 municipal government office buildings after the earthquake struck on March 11. Figure 3 below illustrates the responses by the ICT divisions of these ten municipalities, whether emergency power generators operated and for what purposes they were used.

Figure 3: Responses by ICT divisions to the suspension of power supply



Emergency power generators were used to supply power to server rooms in Sendai City and Ishinomaki City. Besides the server room, however, in the Sendai City government office and the local ward office, power was supplied only to lighting fixtures. As there was no power supply to the computer terminals and other equipment required to recommence operations and little prospect of power being resumed soon, the servers were shut down temporarily after data backup was completed. In Ishinomaki City, power was supplied to lighting fixtures within the server room, but not to the mainframe computer.

In Kesennuma City and Minamisanriku Town, emergency power generators were used to operate the servers (including temporary servers) for approximately two days from March 15 and about a month from March 22 respectively, before normal power supply was resumed. In Kesennuma, restrictions were placed on system operation times and access made possible to vital information on residents that was necessary to confirm their whereabouts and safety. At the temporary office in Minamisanriku, laptops were used as servers and all systems were operated using power from emergency power generators until commercial power supply was made available from late May.

The Otsuchi Town Central Community Hall, where the emergency response headquarters was located, is equipped with emergency power generators. Temporary server 1 was installed here and operated for some time using power from the emergency power generators. After about a week power supply was switched to a ground power unit, following which commercial power supply was resumed and temporary server 2 was installed, enabling the provision of various resident services such as *inkan* registration and certification and issue of resident cards. Beginning April 25, operations were moved to a temporary office building with commercial power supply utilizing feeder panels installed at the neighboring Otsuchi Elementary School (see Table 4).

Table 4: Status of power supply at the municipal government office buildings immediately after the March 11 disaster and power resumption timing

Municipalities surveyed		Suspension of power supply	Status of power supply at the municipal government office buildings (including use of emergency power generators)	Power resumption timing
Iwate Prefecture	Miyako City	Yes	Power supply to lighting fixtures using compact emergency power generator	March 26
	Rikuzentakata City	Yes	Power supply to lighting fixtures using emergency power generator	March 14 (only areas where emergency response headquarters were set up)
	Kamaishi City	Yes	Emergency power generator installed at Building 1 after the disaster to supply power to lighting fixtures.	Mid July (March 20 to server room and peripherals)
	Otsuchi Town	Yes	Power supply using emergency power generator; about a week after the disaster switched to a ground power unit (both at the Central Community Hall, where the emergency response headquarters was located)	March end (to the Central Community Hall) April 25 (to the temporary office)
Miyagi Prefecture	Sendai City	Yes	Power supply to lighting fixtures and emergency equipment using emergency power generator (emergency power generator used at the Information Systems Center where the server room is located, but since there were no prospects for early resumption of power, use was discontinued on the night of March 11)	March 12 (March 13 to the Information Systems Center)
	Ishinomaki City	Yes	Power supply to server room and lighting fixtures using emergency power generator	March 26
	Kesennuma City	Yes	Power supply to the emergency response headquarters and computing systems from March 15 using emergency power generator leased by a local electrical utility	March 17
	Higashimatsushima City	Yes	Power supply to the emergency response headquarters only using emergency power generator	March 15
	Minamisanriku Town	Yes	Power supply to the emergency response headquarters and temporary office using	May end (temporary office)

			emergency power generator	
Fukushima Prefecture	Iwaki City	No	-	-
	Minamisoma City	No	-	-
	Futaba Town	No	-	-
	Namie Town	Yes	Details not known	March 12

Immediately after the disaster, the Miyako City municipal main office moved its servers to the Niisato office that is situated further inland and is better equipped with larger emergency power generators that can support server operation. From March 14, normal power supply was resumed in the Niisato area and the servers could be operated without utilizing the large emergency power generators.

5. Telecommunications infrastructure

In this section we analyze telecommunications infrastructure in the disaster areas from the perspective of intra- and inter-regional means of communication. Communication networks within the municipal government office buildings and public networks within the region are referred to as 'intra-regional communication means', while 'inter-regional communication means' indicate landline telephones, mobile phones, internet and satellite phones. 'Public networks within the region' refer to communication networks that link users to facilities providing government services and to the municipal government office buildings.

5.1 Telecommunications infrastructure--intra-regional communication means

Communication networks at 11 of the 13 municipal government office buildings surveyed were disrupted immediately after the earthquake and tsunami due to power failures and damage to communication cables.

At the Miyako City, Kamaishi City, Sendai City, Kesennuma City, Higashimatsushima City and Namie Town government office buildings, communication networks returned to normal as soon as power supply was restored. Damaged communication cables disrupted networks in the Sendai City, Ishinomaki City and Iwaki City government office buildings. In Sendai City, which experienced both power failure and damage to cables, restoration of public networks was delayed even after government office networks became operational. Communication networks were newly installed within the temporary offices of the Rikuzentakata City, Otsuchi Town and Minamisanriku Town municipalities in conjunction with relocation (see Table 5).

The raised access floor of the server room in the Ishinomaki City government office building was flooded by the tsunami, submerging all power sources and communication cables in the floodwater. However, due to lack of fuel and related logistics issues, replacement of the cables could not be done before April. As a result, the ICT division was compelled to continue using the wet cables, despite fears of short circuits and interrupted communications.

With regard to public networks within the region, communications have yet to be restored in some areas. Reasons for this delay include cables washed away by the tsunami, collapse of utility poles, destruction of cables due to land subsidence and other damage, and uncertain plans regarding future use of land in the devastated areas.

In Ishinomaki City and Higashimatsushima City, that have their own optical fiber network, employees of the ICT divisions are visiting different areas to assess the damage and restore networks wherever possible with support from the National government—a time-consuming process. In Minamisanriku Town, surveys are still underway to gauge the destruction to the town's self-operated optical fiber network.

Table 5: Damage to intra-regional communication means and date of restoration

(As of January 2012)

<table>
<tr><td colspan="2" rowspan="2">Municipalities surveyed</td><td colspan="2">Damage suffered</td><td colspan="2">Date of restoration</td></tr>
<tr><td>Government office building networks</td><td>Public networks within the region</td><td>Government office building networks</td><td>Public networks within the region</td></tr>
<tr><td rowspan="4">Iwate Prefecture</td><td>Miyako City</td><td>×</td><td>Partially disrupted</td><td>March 26</td><td>June</td></tr>
<tr><td>Rikuzentakata City</td><td>×</td><td>No sites that offer government services</td><td>Switching to new networks on July 23</td><td>September and later</td></tr>
<tr><td>Kamaishi City</td><td>×</td><td>× (Networks linking Buildings 1 - 5)</td><td>Mid July</td><td>Mid July</td></tr>
<tr><td>Otsuchi Town</td><td>×</td><td>- (1)</td><td>Late April</td><td>-</td></tr>
<tr><td rowspan="4">Miyagi Prefecture</td><td>Sendai City</td><td colspan="2">Disrupted due to power failure and partial destruction of cables</td><td colspan="2">March 16</td></tr>
<tr><td>Ishinomaki City</td><td>×</td><td>Cables partially washed away</td><td>March 26 (Cable replacement on April 30)</td><td>May to October (Partial disconnection continues)</td></tr>
<tr><td>Kesennuma City</td><td>×</td><td>Cables partially washed away</td><td>March 17</td><td>April to September end</td></tr>
<tr><td>Higashimatsushima City</td><td>×</td><td>Cables partially washed away</td><td>March 15</td><td>Not restored where cables were washed away</td></tr>
</table>

	Minamisanriku Town	×	Cables partially washed away	By April end	May 25(new installation)
Fukushima Prefecture	Iwaki City	×	Cables partially destroyed	March 12	December (not restored in some areas)
	Minamisoma City	○	○	-	-
	Futaba Town	○	(No sites that offer government services)	-	-
	Namie Town	×	Details not known	March 12	Details not known

×: network not operational; ○: network operational

(1) Otsuchi Town has a branch office, but it is not linked to the network.

5.2 Telecommunications infrastructure--inter-regional communication means

In many of the prefectures affected by the disaster, all means of communication with the outside were lost due to power failure, resulting in 1- 2 weeks of isolation. The only communication means during this time was by satellite telephone, distributed mainly to emergency response headquarters. Satellite phones, however, are rarely used in daily life and comments regarding their usage included statements such as, " We don't know how to use a satellite phone," "We don't have contact numbers," "(The phone number was not made public), but there was a leak of information and we received numerous general enquiries at that number, hindering usage during emergencies." Other problems associated with its usage were poor connectivity due to telephone congestion control as all affected prefectures began using the telephone at once, and short battery life that prevented frequent use.

Suspension of power made it impossible to get external information via television and radio, and as a result some areas did not have any access to information. With no proper means of acquiring information and all communication with the outside cut off, many of the municipalities could not even send out requests for help.

In Higashimatsushima City, Iwaki City, Minamisoma City and Futaba Town, Internet services were disrupted due to connectivity problems other than power failure.

Landlines, mobile phones and the Internet were operational in Minamisoma City on March 11, however, all these services were disrupted for a week from the 12th, isolating the city from the rest of the world (see Table 6).

Table 6: Status of inter-regional communication means and timing of restoration, and use of satellite mobile phones

Municipalities surveyed		Status of usage *1 (March 11)			Timing of restoration			Use of satellite mobile phones*3
		Landlines	Mobile phones*2	The Internet	Landlines	Mobile phones	The Internet	
Iwate Prefecture	Miyako City	×	Δ (1)	×	From April	-	March 26	○
	Rikuzentakata City	×	×	×	Details unknown	From March 18	From July at the temporary office	○
	Kamaishi City	×	×	×	From March 18	Around March 18	March 20	○
	Otsuchi Town	×	×	×	April 25	Around March 20	Around May 25	○
Miyagi Prefecture	Sendai City	○	Δ (2)	×	-	Around March 14	March 13	○
	Ishinomaki City	×	×	×	Around March 26	Around March 26	Around March 26	○
	Kesennuma City	×	Δ (3)	×	March 21	From mid-March	March 17	○

	Higashimatsushima City	×	×	×	From March 17	By March end	March 17	○
	Minamisanriku Town	×	×	×	From late March	From April	March end	No arrangements
Fukushima Prefecture	Iwaki City	○	○	×	-	-	March 12	○
	Minamisoma City	○ (From March 12 ×)	○ (From March12 ×)	○ (From March 12 ×)	Around March 19	Around March 19	Around March 19	Poor connectivity
	Futaba Town	○	Δ (4)	×	-	Around March 18	4:30 p.m. on March 11	No arrangements
	Namie Town	×	×	×	Details unknown	Details unknown	late May	○

*1: Could not be used: ×, Could be used: ○, Could be used with some restrictions: Δ

*2: Information on the status of usage of mobile phones is as stated by the survey respondents. The status of usage of mobile phones immediately after the disaster and the timing of restoration varies by telecommunications service provider and area.

*3: The user was not always the ICT division.

(1) Mobile phones could be used between only a few telecommunications service providers.

(2) Varies by telecommunications service provider and area.

(3) Could be used until around 10 p.m. on March 11.

(4) Could be used only to send and receive e-mails, not to make phone calls

Satellite mobile phones were not distributed to Miyako City and Namie Town on March 11, but were provided later as part of relief supplies. Namie Town received satellite mobile phones from Fukushima Prefecture when the town office was relocated to the Tsushima branch office, also in the same town. Rikuzentakata City had equipped its government offices with satellite mobile phones, but the instruments at the main government office building were destroyed by the tsunami. Of all the satellite mobile phones distributed among the 11 district headquarters, only two units at the district headquarters along the mountains remained operational.

Futaba Town received an offer from a private business for the leasing of satellite mobile phones, but could not accept the offer as the offices had to be relocated several times.

6. Information processing systems

In this section we analyze the data backup measures of information processing systems operated and managed by the ICT divisions of the municipalities surveyed, the status of data usage after the disaster, the relation between systems recovery and re-commencement of resident service counters, and information processing systems that are required to conduct disaster response operations. We focused on four information processing systems, namely, The Basic Resident Registration, Family Registration, Tax, and Social Security systems. At two of the 13 municipalities surveyed, the ICT divisions were responsible for operation and management of the family registration system -- Otsuchi Town and Namie Town. The information processing systems listed in Table 7 are operated and managed by the ICT divisions of each municipal governments.

6.1 Data backup measures

The data backup measures at each of the municipalities are centered on three elements: place of storage (within the main government office building/outside the main government office building (within the town or city/outside the town or city)), method of storage, and frequency of backup.

As of March 11, three of the 13 municipalities surveyed (Kamaishi, Ishinomaki and Iwaki) had data stored outside the main government office building (within the town or city) and two (Sendai and Namie) at remote locations outside the town or city.

Most government offices used tapes to backup data and the tapes were stored in the server room. Ishinomaki City, Minamisanriku Town and Namie Town had backed up data on the server hard disk drive.

The frequency of data backup varied by municipality, however, all 13 municipalities surveyed backed up files on a daily to weekly basis.

With regards to data backup and recovery regulations, most municipalities had no organization-wide standards for data backup. Each ICT division determined the place of storage and backup frequency of files in information processing systems that were managed and operated by them. Business divisions in charge of management and operation of application software established individual procedures for system operation and data backup. The ICT division of the Sendai City government office, however, had an information security policy and has established procedures for implementing security measures related to information processing systems under their supervision, as well as unified standards for data backup. For systems managed by individual business divisions, operating guidelines were drawn up by division, which also specified data backup and recovery procedures.

Table 7: Data backup measures

(As of March 11, 2011)

Municipalities surveyed		Information processing system	Backup frequency	Storage method	Place of storage*	
					Within the government office building	Outside the government office building
Iwate Prefecture	Miyako City	Residents' information system (Basic Resident Registration Network, Tax and Social Security systems)	Daily	Tapes	○	-
	Rikuzentakata City	The Basic Resident Registration Network System (including Social Security) and Tax systems	Daily	Tapes	○	-
	Kamaishi City	Basic Resident Registration Network	Daily	External storage media	○	×
	Otsuchi Town	Basic Resident Registration Network, Family Registration, Tax and Social Security systems	Daily	Tapes	○	-

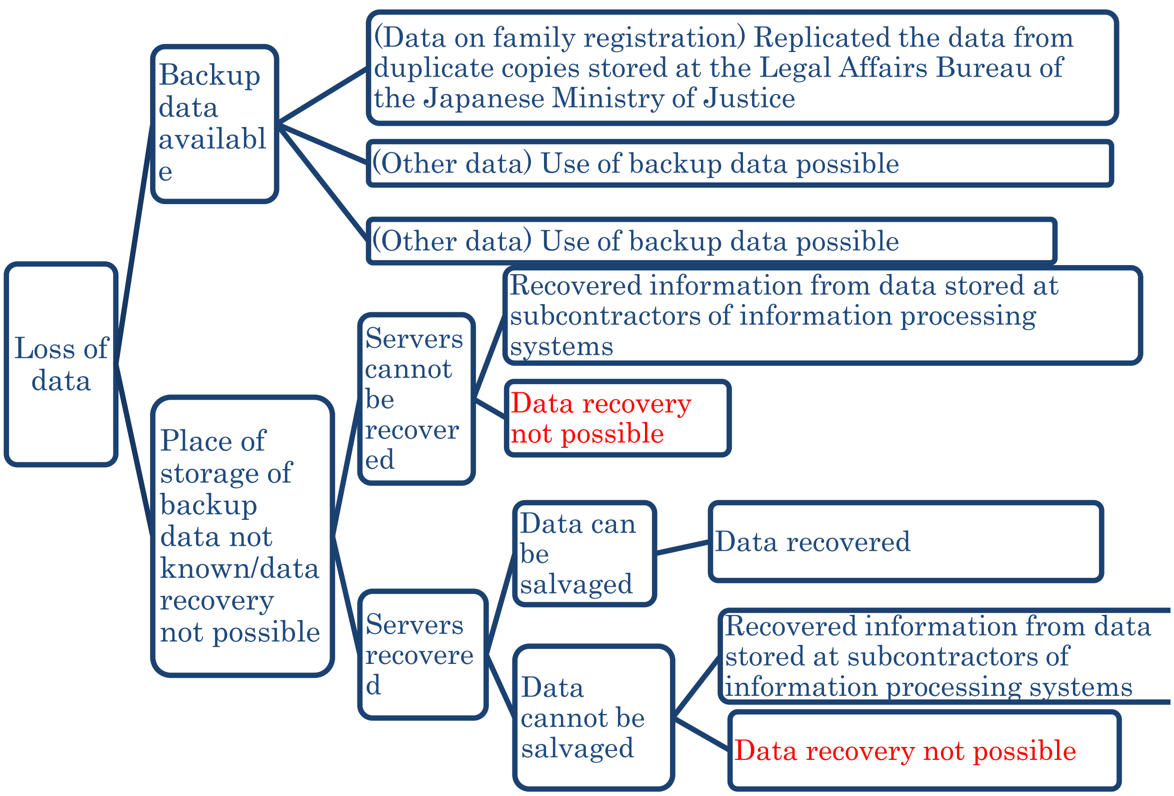
Miyagi Prefecture	Sendai City	Basic Resident Registration Network, Tax and Social Security systems Note: Operated by a local information processing systems center (specified as the government office)	Daily (within the government office building) Once a month (outside the city)	Tapes	○	○ (outside the city)
	Ishinomaki City	Basic Resident Registration Network and Tax systems	Weekly (within the government office building) Once a month (at an external location)	Server hard disk drive (within the government office building) Tapes (at an external location)	○	○ (within the city)
	Kesennuma City	Residents' information system (Basic Resident Registration Network, Social Security systems and tax)	Daily	Tapes	○	-
	Higashimatsushima City	Basic Resident Registration Network, Tax and Social Security systems	Weekly	Tapes	○	-
	Minamisanriku Town	Basic Resident Registration Network, Tax and Social Security systems	1 – 2 times a week	Tapes and server hard disk drive	○	-
Fukushima Prefecture	Iwaki City	Basic Resident Registration Network system	Daily	Tapes	○	○ (within the city)
	Minamisoma City	Basic Resident Registration Network, Tax, Social Security and Family Registration systems (all managed by business divisions)	Daily	Tapes	○	-
	Futaba Town	Residents' information system (including Tax, and Social Security)	Daily	Tapes	○	-
	Namie Town	Basic Resident Registration Network, Tax, and Social Security systems	Daily	Server hard disk drive and	○	○ (outside the

				tele-trans mission		town)

*○: stored, -:not stored

The Rikuzentakata City, Otsuchi Town and Minamisanriku Town government office buildings were completely devastated by the tsunami and the data servers were either submerged in or washed away by the floodwaters. None of the three municipalities had backup data stored at locations outside the government office buildings, and for a while it seemed that all digital data had been lost. Based on the events that took place at the three municipalities, the instances of the loss of data to recovery can be classified as shown in Figure 4 below.

Figure 4: Instances of data loss and recovery



Municipalities that belong to each instance are as follows:

<u>Backup data</u>

- Replication of family registration[*] digital data from duplicate copies stored at the Legal Affairs Bureau…Rikuzentakata City, Otsuchi Town and Minamisanriku Town
- Use of backup data possible…None applicable
- Recovery of backup data not possible…Rikuzentakata City

<u>Place of storage of backup data not known</u>

- Servers cannot be recovered…Minamisanriku Town
- Recovered the submerged data servers and salvaged files from the server hard disk drive…Rikuzentakata City, Otsuchi Town

  (Rikuzentakata City, Otsuchi Town and Minamisanriku Town utilized the backup data stored at subcontractors of information processing systems until files were recovered.)

While waiting for data from the server hard disk drive to be recovered, Rikuzentakata City commenced the creation of a temporary system based on the Basic Resident Registration Network information (hereafter called 'Juki Network data') as of the end of February, stored at subcontractors of information processing systems. Similarly, a temporary finance and accounting system was created using finance and accounting information (hereafter called 'financial data') as of January 23, stored at the same subcontractor of information processing systems. Only Juki Network data, Social Security information (hereafter called 'Social Security data') and data related to tax returns were later recovered from the server hard disk drive.

[*] In Japan there are two primary citizen registration database, one recording current residence and the other registering family connections.

Information from the Family Registration system (hereafter called ‘Family Registration data’) was replicated from copies stored at the Legal Affairs Bureau of the Japanese Ministry of Justice. All other data was lost.

Similarly, in Otsuchi Town temporary systems were created using Juki Network data and data related to tax returns (hereafter called Tax data) as of March 1, stored at subcontractors of information processing systems. Juki Network data and Tax data were later recovered from the server hard disk drive, but Social Security data could not be restored. The server on which Family Registration data was stored could not be salvaged, and digital files of information up to February 2011 were recreated from copies stored at the Legal Affairs Bureau and from applications received after the disaster.

In Minamisanriku Town, the servers were all washed away and could not be retrieved. In addition, all backup data stored at the main government office building was also washed away and for a while it seemed that all resident information had been lost. By chance, however, it was later found out that the subcontractor of information processing systems had backup data from the core systems of the Juki Network, tax, employee salaries, accounts, caregiving, and national insurance, stored at their facilities, with information updated up to March 4. This was the only backup data that could be recovered and was used to create a provisional system after relocation to the temporary office building. All other file servers, excluding that for the core systems, had no backup done at external locations, resulting in a complete loss of data. Family Registration data was recreated from copies of digital files stored at the Legal Affairs Bureau.

Although no data was lost, Ishinomaki City, Futaba Town and Namie Town used backup data at some resident service counters after the disaster. Certificates of residence (with the ‘Family relationship’ column left blank) issued by Ishinomaki City on March 28 utilized backup data as of March 11 on resident information. The Futaba Town government office that was relocated to the Saitama Super Arena used resident information backup data stored at an information processing systems subcontractor to issue Disaster-victim Certificates. Backup data stored at the Futaba Town government office building was retrieved when functions were temporarily moved back to the town. When the Namie Town government office was relocated to the Towa Area of Nihonmatsu City, a simply configured data server was installed using backup data stored at a data storage center outside the town, following which the temporary office building and the center were linked by a computer network.

Table 8: Usage of backup data

Municipalities surveyed		Status of data loss (Data in the information processing systems listed in Table 7)*1	Usage of backup data*2	Place of storage of backup data used	
				Within/without the government office building	Information processing systems subcontractor
Iwate Prefecture	Miyako City	-	-	-	-
	Rikuzentakata City	○ (Recovered from the server hard disk drive)	Backup data stored at information processing systems subcontractor used	Data recovery measures not taken	○
	Kamaishi City	-	-	-	-
	Otsuchi Town	○ (Recovered from the server hard disk drive)	○ (Backup tapes could not be retrieved)	Not retrieved	○
Miyagi Prefecture	Sendai City	-	-	-	-
	Ishinomaki City	-	○	○	-
	Kesennuma City	-	-	-	-
	Higashimatsushima City	-	-	-	-
	Minamisanriku Town	○ (Servers washed away)	○ (Backup tapes could not be retrieved)	Not retrieved	○
Fukushima Prefecture	Iwaki City	-	-	-	-
	Minamisoma City	-	-	-	-
	Futaba Town	-	○	○	○
	Namie Town	-	○	○	-

*1: ○: Lost, -: Not lost

*2: ○: Used, -: Not used

**: Family Registration data lost at Rikuzentakata City, Otsuchi Town and Minamisanriku Town was recreated using duplicate files stored at the Legal Affairs Bureau.

As a post-disaster measure, Rikuzentakata City eliminated the use of tapes for storing data and as a general rule for the entire office, switched to the use of server hard disk drives. Individual system configurations, however, necessitate the use of unique data backup methods.

After moving to the temporary government office building, Otsuchi Town installed standby data servers in the server room for the Juki Network, Family Registration, Tax and Social Security systems and is currently duplicating all information. Further, remote backup of the Juki Network system via LGWAN was commenced in December 2011.

In their temporary office buildings, Minamisanriku Town and Futaba Town linked their systems to those of information processing systems subcontractors via computer networks that are currently being used to conduct business. Data backup locations outside the towns are also being used (excluding Family Registration data, which is being backed up within the respective temporary office buildings).

In the summer of 2011, employees of the Ishinomaki City government office independently developed a system that enables daily data backup on the server hard disk drive, and operation of the system by the ICT division has begun.

6.2 Damages to and recoveries of information processing systems managed and operated by ICT divisions

Table 9 shows the location of the server room in each municipal government office at the time the disaster struck

Table 9: Server room location

(As of March 11, 2011)

Municipalities surveyed		Server room location
Iwate Prefecture	Miyako City	Second floor of seven-storied government office building
	Rikuzentakata City	First floor of three-storied (four in some sections) government office building
	Kamaishi City	Not disclosed
	Otsuchi Town	Second floor of two-storied government office building
Miyagi Prefecture	Sendai City	External location (information processing systems center within the city)
	Ishinomaki City	First floor of seven -storied government office building and second floor of branch office
	Kesennuma City	Second floor of three-storied government office building and third floor of three-storied Densan Center situated close to the office building
	Higashimatsushima City	Second floor of three-storied government office building
	Minamisanriku Town	Second floor of three-storied Disaster Prevention office adjoining the government office building
Fukushima Prefecture	Iwaki City	Seventh and eighth floors of eight-storied government office building
	Minamisoma City	Third floor of four-storied government office building
	Futaba Town	Second floor of four storied government office building
	Namie Town	Second floor of four storied government office building

The Kamaishi City and Sendai City municipalities had installed server rooms at locations besides the government office that housed the ICT divisions. The information processing Systems Center in Sendai City was like a branch office with ICT division employees stationed there permanently.

Iwaki City moved its data servers to an external, and safer, location in September 2011.

Rikuzentakata City installed data servers within the temporary government office building; Otsuchi Town in the Central Community Hall; and Minamisanriku Town in the data storage center of an information processing systems subcontractor. Minamisanriku Town operates its Family Registration data server within the temporary government office building.

Futaba Town initially operated temporary systems within the Saitama branch office, and later moved its data servers to the data storage center of an information processing systems subcontractor. Namie Town had used a data storage center even before the disaster, and after relocating to the Towa Area, Nihonmatsu City office used a computer network to link systems to the data center.

Looking next at the dates when power supply was resumed, operation of information processing systems was recommenced and resident service counters were reopened, it can be seen that, most municipalities prioritized the operation of information processing systems as soon as power supply was resumed, followed by the reopening of resident service counters for the issue of certificates and other documents. (see Table 10).

Table 10: Dates when power supply was resumed, operation of information processing systems was recommenced and resident service counters were reopened

Municipalities surveyed		Power supply resumed	Operation of information processing systems recommenced	Resident service counters reopened
Iwate Prefecture	Miyako City	March 26	March 14	March 14
	Rikuzentakata City	March 14 (only areas where disaster response headquarters were set up)	March 23 (provisional)	Beginning March 23
	Kamaishi City	Mid July (data server and peripherals March 20)	April 1 (moved to another facility)	April 1
	Otsuchi Town	April 25 (at the temporary government office building)	March 29 (temporary server 1), April 13 (temporary server 2)Power supply to both servers from ground power units)	April 13
Miyagi Prefecture	Sendai City	March 12 (March 13 to the Information Systems Processing Center)	Online services were resumed on March 17	March 14
	Ishinomaki City	March 26	March 26	Partially reopened on March 28 All counters reopened on April 11
	Kesennuma City	March 17	March 15 (power supply from emergency power generators), all systems resumed from 17	From March 22
	Higashimatsushima City	March 15	March 16	From mid April
	Minamisanriku Town	Late May (at the temporary government office building)	March 28 (power supply from emergency power generators)	Partially reopened on March 28 Other counters reopened beginning April 29
Fukushima Prefecture	Iwaki City	-	Operation not disrupted	March 14
	Minamisoma City	-	Operation not disrupted	March 14
	Futaba Town	-	April 18 (at the Saitama branch)	April 18

	Namie Town	March 12	April 4 (a simply configured data server was set up in Towa Area of Nihonmatsu City) Late April (at a data storage center in Iwaki City)	Beginning mid April

On March 29, Otsuchi Town transferred backup data to temporary server No. 1 that was used to access residents' information. Temporary server No. 2 was installed on April 13 and the issue of certificates and other documents was recommenced.

In Sendai City, applications on paper continued to be accepted for services for which paper ledger could be used. Certificates of residence with the 'Family relationship' column left blank were issued by Ishinomaki City on March 28, the last working day of the fiscal year, utilizing backup data. Power was supplied to the mainframe computer between March 26 and April 11 and information input on March 11 and thereafter was transferred to the mainframe computer. In Kesennuma City, emergency power generators were used to supply power to operate servers and enable access to residents' information only from March 15 to 17, when normal power supply was resumed. As Higashimatsushima City prioritized disaster response measures and recommenced operation of information processing systems, and resident service counters, and these were carried out later than other municipalities.

Miyako City first moved its servers to the Niisato office situated further inland and functions such as issuing certificates were conducted here. As computer networks within the municipal government office buildings and public networks within the region were not yet operational at this time, applications received at the main government office building and at branch offices were transported to the Niisato office the same day and processed for delivery the following day. Family Registration data utilized as personal identification information for applications received on weekends was installed on three laptops and used without linking to a computer network.

6.3 Disaster response measures and information processing systems

The response measures summarized below require a large number of people working at the disaster site to carry out numerous activities, including creating lists of survivor names and other information, manning resident service counters to issue Disaster-victim Certificates required to avail of disaster relief and other support systems, distribution of relief money, accepting applications for temporary housing, and tearing down damaged buildings and clearing debris.

The disaster response measures taken by the ICT divisions of 13 municipalities surveyed can be primarily divided into the following:

1) Documenting evacuee names and other information (on paper)

2) Documenting evacuee names and other information (on the computer)

3) Restoring operation of information processing systems

-Upgrade of existing systems

-Development and introduction of new systems

4) Verifying information in various lists with previously documented residents' information

5) Issuing of Disaster-victim Certificates

1) and 2) are extremely labor-intensive tasks and most of the municipalities made significant efforts to complete this unexpected post-disaster duty that employees also found demanding.

Information processing systems that were restored or newly introduced and the timing of measures taken differ by municipality. The system types may, however, be broadly divided into the following two types:

-Systems based on residents' information that link to all government functions

-Individual systems for each function (issue of Disaster-victim Certificates, distribution of relief funds, etc.)

The Disaster Victims Support System is one example of an existing system that is based on residents' information and links to all government functions. Survey respondents were also asked questions about the introduction of this system. Although none of the municipalities had installed the system before March 11, 2011, Miyako City, Ishinomaki City, Kesennuma City, Minamisanriku Town and Iwaki City, have introduced it since and selectively use only those features of the system that are required for their individual operations. Miyako City utilizes the system to manage distribution of relief funds; Ishinomaki City for the issue of Disaster-victim Certificates; Kesennuma City for the management of debris removal; and Minamisanriku Town to manage distribution of relief funds and occupancy of temporary housing facilities.

Table 11 below lists the date of issue of Disaster-victim Certificates by each municipality and the information processing systems that were introduced. Issuing of certificates as part of regular duties was resumed on the same day that resident service counters were reopened at each municipality.

Table 11: Dates when resident service counters were reopened, Disaster-victim Certificates were issued and status of development and introduction of information processing systems

(As of January 2012)

Municipalities surveyed		Reopening of resident service counters	Issue of Disaster-victim Certificates	Status of development and introduction of information processing systems ( )indicates the system operation start date
Iwate Prefecture	Miyako City	March 14 (Niisato office) March 27 (main office building)	Around March 20	Disaster Victims Support System (mid-May) Disaster Victim's Information Registration and Retrieval System (December 22)(1)
	Rikuzentakata City	Beginning March 23	April 27	Not introduced
	Kamaishi City	April 1	Beginning early April	Developed an original Disaster Victim's Information Registration and Retrieval System (April 18)
	Otsuchi Town	April 13	April 27	System for the issue of Disaster-victim Certificates (National Research Institute for Earth Science and Disaster Prevention) (April 27) Disaster Victim's Information Registration and Retrieval System (around May)(1)
Miyagi Prefecture	Sendai City	No disruption	Beginning around March 23	Disaster Victim's Information Registration and Retrieval System (upgrade of existing system, after Golden Week holidays)
	Ishinomaki City	Partially on March 28 All counters reopened on April 11	Beginning from Golden Week holidays	Disaster Victims Support System (Beginning from Golden Week holidays)
	Kesennuma City	From March 22	April 18	Disaster Victims Support System (April - May) Developed original Disaster -victim Certificates database and Disaster Health Information Management System (Beginning mid April)
	Higashimatsushima City	From mid-April	April 4	Developed original Disaster Victim's Information Registration and Retrieval System (April 18)
	Minamisanriku	Partially on	Early May	System for the issue of Disaster-victim Certificates

	Town	March 30 All counters reopened beginning April 29		(provided by subcontractor of information processing systems) (late March) Disaster Victims Support System (November)
Fukushima Prefecture	Iwaki City	March 14	April 4	Developed original Disaster Victim's Information Registration and Retrieval System (late May) Disaster Victims Support System (November end)
	Minamisoma City	March 14	Beginning April 25	Developed original Disaster Victim's Information Registration and Retrieval System (April)
	Futaba Town	April 18	June 22	Introduced an information processing systems managed by a call-center type system (around March 20)
	Namie Town	Beginning mid-April	March 22	Developed original Disaster Victim's Information Registration and Retrieval System (March 23)

(1) A system created and provided through collaboration between industry, government and academia, under the guidance of Haruo Hayashi, Professor at the Disaster Prevention Research Institute, Kyoto University. Iwate Prefecture takes the initiative in constructing the system and providing operational support to municipalities whose administrative functions have weakened due to the effects of a disaster.

Most municipalities commenced issuing Disaster-victim Certificates beginning in April.

Higashimatsushima City began operations related to issuing Disaster-victim Certificates simultaneously with start of system development. Initially management of applications received and certificates issued was done on paper, and data entries were made after system development was completed. In Namie Town, applications were initially processed on paper, but as this proved to be a time consuming and burdensome job, operation of the system was begun from the very next day after development was completed. After the disaster, Kamaishi City applied for the product key required to install the Disaster Victims Support system, but had to abandon the plan due to system architecture and data loading problems.

Following the disaster, many municipalities considered introduction of the Disaster Victims Support system, but were forced to defer introduction for the following reasons:

-Installation on data server was not successful

-Data processing is required, making use of the system cumbersome

-A drop in performance was expected when handling large volumes of data

-Studying the system and customizing could not be completed in time for issue of the certificates

-Operational differences with the developer (Nishinomiya City) regarding the format of the Disaster-victim Certificate and other issues

-Information upload regarding disaster victims was already completed using a different application software

All of the problems mentioned in the above comments could have been avoided if preparations had been made in normal times to configure the system beforehand and train personnel to be able to upload resident information immediately in the event of a disaster.

On the other hand, as many post-disaster tasks cannot be foreseen, it is often difficult to determine beforehand what information upload will be required (and what will not) during a disaster. The following are examples of items that cannot be confirmed earlier and require some form of technical support to upgrade the system as may be needed after a disaster.

-No record of relocation history of evacuees

-Information on temporary housing choices of evacuees cannot be uploaded

-Information on management of relief goods cannot be updated

-No feature to record transactions at resident service counters

The operation of information systems to deal with disaster response measures, including the Disaster Victims Support system, requires more than just installing the system on a server. As explained above, emergency preparedness measures must be taken to enable uploading of resident information immediately after a disaster, and training to ensure business continuity and provide support to victims must be implemented beforehand.

In addition, not just considering introduction of system for disaster response measures, steps must also be taken to ensure speedy coordination between systems to enable extraction of information from the existing resident information system and conversion to the new format.

7. Business relations with subcontractors of information processing systems

Although some of the 13 municipalities surveyed had specified clauses in their contracts regarding measures that must be taken by subcontractors of information processing systems in the event of a system failure, none of the contracts included action anticipating natural disasters.

In this survey, we asked participants about their business relations with subcontractors of information processing systems and the kind of assistance they received during the recovery process. The contents of responses received (although fragmented) regarding the role played by subcontractors of information processing systems have been summarized below. We can see that they worked together with employees of ICT divisions on almost all operations related to system recovery and also contributed significantly to municipalities that had to relocate their offices, particularly through the provision of ICT equipment. In addition, they also played a major role in helping municipalities recover lost data by transferring backup files stored at their facilities as part of the subcontracting agreement.

The main forms of support received by each municipality are summarized in Table 12 below.

Table 12: Main forms of support provided by subcontractors of information processing systems

(As of January 2012)

Municipalities surveyed		Main forms of support received (limited to the forms of support identified through this survey)
Iwate Prefecture	Miyako City	Worked together with ICT division employees to relocate data servers
	Rikuzentakata City	Provided backup data, helped recover data server hard disk drives a week after submerging and salvage data
	Kamaishi City	Laying of cables by telecommunications carrier
	Otsuchi Town	Helped recover data server hard disk drives, restore data and configure systems, and provided

		equipment
Miyagi Prefecture	Sendai City	Checked the condition of data servers and other equipment at the information processing systems center
	Ishinomaki City	Verified system damage and upgraded the Disaster Victims Support system
	Kesennuma City	Conducted inspections of data servers
	Higashimatsushima City	Supervised the export of Juki Network data to configure the Disaster Victim's Information Registration and Retrieval System
	Minamisanriku Town	Provided backup data, configured systems and provided equipment
Fukushima Prefecture	Iwaki City	Checked the safety features of the data server room
	Minamisoma City	Provided equipment
	Futaba Town	Provided backup data and computer terminals, and helped introduce the call center-type system
	Namie Town	Helped configure simple data servers after relocation and provided computer terminals

ICT divisions, even in normal times, play an important role in supporting the business foundations of the entire office and their working relations with other divisions greatly influences the business relationship with subcontractors of information processing systems. Responses to survey questions regarding the information processing systems operated and managed by ICT divisions show that at most municipal government offices, each business division individually manages the operation of exclusive application software, including the signing of agreements with subcontractors of information processing systems. This may be one crucial issue that must be dealt with when considering the future role of ICT divisions at municipal governments.

At most of the 13 municipalities surveyed, the relevant division in charge of family registration matters oversaw the operation of the Family Registration system.

8. Facilities (including computer hardware)

This section provides a summary of the damage to facilities, such as server rooms (including ventilation facilities) and offices (including computer hardware), as well as the available ICT personnel at the time.

The power failure following the disaster cut off server room ventilation systems at most of the municipal government offices. This did not pose a major problem as outside temperatures were not high, and only a few municipalities mentioned this issue during the survey. In Minamisanriku Town, however, where the intensity of damage to the government office building necessitated a move to a temporary location, a server room could not be set up within the temporary government office building. Coupled with concerns regarding the system operational environment when temperatures rose in summer, this led to the decision to install servers (excluding the Family Registration data server) at a data storage center outside the town. Futaba Town could not install a server room within the (now defunct) Saitama Prefectural Kisai High School because it was not certain how long they could continue operations there, and hence switched to the use of servers at a data storage center.

Rikuzentakata City, Otsuchi Town, Minamisanriku Town, Futaba Town and Namie Town had to set up new offices for their ICT divisions after moving to the temporary office building.

In addition to subcontractors of information processing systems, other private businesses also provided tremendous support in recovering and restoring ICT equipment damaged by the tsunami. It is no exaggeration to say that recovery efforts would have been delayed without support from the outside.

With regard to ICT personnel, there was a notable lack of skilled engineers particularly in Rikuzentakata City, Otsuchi Town and Minamisanriku Town, who could develop and maintain ICT operational environments at the temporary government office buildings. ICT division employees from Nagoya City, Hachimantai City and Yahaba Town were sent on long-term assignments to Rikuzentakata City and Otsuchi Town; in Minamisanriku Town, however, the ICT division received only short-term support and when responding to survey questions expressed the need for extended support. Systems must be put in place to provide personnel support in accordance with the needs of the affected municipalities.

Table 13 summarizes the actions taken by survey respondents during the days immediately after the disaster on March 11.

Table 13: Actions taken by ICT division employees during the days immediately after the disaster on March 11

Municipalities surveyed		Actions taken by ICT division employees during the days immediately after the disaster on March 11
Iwate Prefecture	Miyako City	Inspections of server rooms, securing food supplies, etc.
	Rikuzentakata City	After taking refuge on the roof of the government office building for a night, procured and distributed food supplies, blankets and other items, and helped confirm residents' whereabouts
	Kamaishi City	Photographing disaster scenes as part of activities specified under the regional disaster response plan, waiting for power supply to resume
	Otsuchi Town	On a business trip to Morioka, returned on March 12 and helped with the operation of evacuation centers
Miyagi Prefecture	Sendai City	Inspections of server rooms, helped with the operation of evacuation centers and transport of relief goods, network restoration efforts, etc.
	Ishinomaki City	Inspections of server rooms, could not get out because roads around the building were inundated
	Kesennuma City	Inspections of server rooms, helped with the operation of evacuation centers and with preparing the emergency power generators for use
	Higashimatsushima City	Inspections of server rooms, preparing computer terminals for use by the disaster response headquarters
	Minamisanriku Town	Inspections of server rooms, after taking refuge on the roof of the government office building for a night helped with the operation of evacuation centers
Fukushima Prefecture	Iwaki City	Inspections of server rooms, network restoration efforts
	Minamisoma City	Inspections of server rooms, helped with consolidating information on resident whereabouts, created a website as part of activities specified under the regional disaster response plan
	Futaba Town	Inspections of server rooms, evacuated to Kawamata Town on March 12
	Namie Town	Inspections of server rooms, evacuated to the Tsushima branch office on March 12

Kamaishi City had installed its server room in a building other than the Government Office Building 1 where the ICT division office was located. Immediately after the disaster, the area around Building 1 was covered with debris making it impossible to go outside and check the condition of the servers. Moreover, the server room door was fitted with a digital lock that could not be opened until power supply to the building was resumed around March 20 (the conventional door lock was lost during the devastation).

9. Lessons learned: Future measures that must be implemented by ICT divisions of municipal governments

One of the key findings of this survey is the fact that at the time the disaster struck none of the municipalities surveyed had action plans that included business continuity planning (BCP) for their relevant ICT divisions. Disaster response measures taken by the municipalities were typically left to the discretion of the people in charge of each division, and we could not confirm what action was taken by ICT division supervisors in the areas where ICT division employees became victims to ensure business continuity. Although subcontractors of information processing systems and other private businesses contributed significantly to the recovery process, there were no shared disaster response procedures.

Secondly, the management of application software and electronic data was mostly entrusted to individual business divisions and not only were there no standard guidelines regarding data backup, in some government offices the relevant ICT division was not aware of what kind of data was being stored and the storage methods being used. The most important factor impeding recovery was the loss of data.

Based on these and other findings from our survey, we have outlined future measures that must be implemented by ICT divisions of municipal governments in the following two areas, i.e., 1) Creation of business continuity plans, and 2) Collaboration between diverse entities

9.1 Creation of business continuity plans

In order to put to good use the findings of this survey towards drafting effective business continuity plans, the types of risks observed at the 13 municipal government office buildings following the earthquake and tsunami and the situations that arose subsequently are described here.

- Collapse of government office buildings
- Damage to the server, ventilation systems and other equipment
- Loss of electronic data
- Suspension of power supply
- Damage to telecommunications cables and equipment (disruption of communications)
- Destruction of office automated systems
- Difficulty in getting employees and other personnel to the government office building
- Inability to enter the server room
- Relocation of the server room
- Relocation of administrative functions

Further, in areas affected by the nuclear accident, access to the government offices is difficult for local and outside personnel despite no damage to the buildings themselves, and relocation of data servers outside the region, and of administrative functions is increasingly apparent.

Post-disaster risks could potentially give rise to diverse situations. In particular, a power failure will upset the operation of information processing systems and disrupt communication with the outside. Hence measures to ensure uninterrupted power supply are of utmost importance. During the survey as well, most of the municipal governments emphasized the need for stable power supply. The time taken for commercial power supply to be resumed at the 13 government office buildings varied greatly by municipality, ranging from one day to several months. Although it may be close to impossible to anticipate the time required for power supply to be restored, measures must be implemented to clarify beforehand the tasks that must be carried out during a power failure and to create systems that will ensure uninterrupted power supply to essential ICT equipment. Initiatives must also be taken to prepare for other responses such as the relocation of some administrative functions, in the event of prolonged power outages.

The issues faced by ICT division employees who could not enter the server room for inspections immediately after the disaster included 1) the server room was located in a different building from the ICT division office; 2) the server room door was fitted with a digital lock that could not be opened until power supply to the building was resumed; 3) the conventional door key was lost in the confusion following the earthquake; and 4) floodwater levels remained high and the area was scattered with debris making it impossible to leave the building immediately after the disaster. Municipalities with servers installed at locations away from the ICT division office must investigate safe emergency routes to the server room and the means to enter the room even during a power failure.

The next table lists the response measures necessary to deal with these risks, as indicated by the municipalities surveyed. From the perspective of business continuity planning, provision must be made beforehand to ensure smooth implementation of the measures listed below.

Table 14: risks observed and response measures taken by the municipalities surveyed by types of disasters

Types of disasters	Risks observed	Response measures taken by the municipalities surveyed
Earthquake Tsunami	-Collapse of government office buildings -Damage to the server, ventilation systems and other equipment -Loss of electronic data -Suspension of power supply -Damage to telecommunications cables and	-Implement quake-proofing measures and reinforce structures to enhance quake resistance -Ensure thorough awareness of response procedures and establish communication channels to secure replacements for damaged devices immediately -Establish data backup standards (including the use of cloud computing)

	equipment (disruption of communications) -Destruction of office automated systems (including account processing of balance of leased equipment payment) -Difficulty in getting employees and other personnel to the disaster response headquarters -Inability to enter the server room -Relocation of the server room -Relocation of administrative functions	-Install emergency power generators (and secure fuel supply)and set up ground power units -Install infrastructure for multiple telecommunications systems (satellite, wireless, cellular, etc.), prepare for the use of satellite telephones, and expand communication networks -Establish communication channels to secure replacements for damaged devices immediately and the personnel to install them -Establish emergency communication systems to contact employees, subcontractors and others -Establish programs to receive personnel support from other municipalities -Identify safe emergency routes to server rooms to enable inspections even during power outages -Establish communication channels to secure replacements for damaged devices immediately and investigate methods to recommence operation of the Family Registration system -Determine alternative locations in the event that the main government office building and branch offices cannot be used
Nuclear accident	-Difficulty in getting employees and other personnel to the government office building -Relocation of server room -Relocation of administrative functions	-Measures to secure ICT and other equipment when subcontractors have no access to the area -Determine alternative locations and methods to operate information processing systems at those locations, secure ICT devices and equipment necessary to resume work, and investigate methods to operate the Family Registration system -Determine alternative locations, conclude disaster response agreements with relevant municipal governments, and secure ICT devices and equipment necessary to resume work

Organizing the risks observed by disaster type, we can see that response measures differ for each assumed disaster type--earthquake and tsunami, and nuclear accident.

Further analysis of the recovery stages at the 13 municipalities surveyed reveals that, after the disaster, reopening resident service counters was given less priority compared to tasks such as confirming the whereabouts and safety of residents and setting up and operating evacuation centers, and that these tasks accounted for a significant portion of the work done by ICT division employees during this time.

Their Business Continuity Plans include setting up information processing systems, such as the Disaster Victims Support System, to implement disaster responses; coordinating activities with other divisions; and conducting training on operating information processing systems, including for employees of other divisions. The BCP Guidelines draws awareness to the relationship with information processing systems to implement disaster responses, including the Disaster Victims Support System, and notes that supplementary considerations must be emphasized.

The following is a list of disaster responses identified through the survey. Municipalities that relocated administrative functions due to the nuclear accident conducted responses at the alternative location.

- Establishing and operating evacuation centers
- Transport and management of relief goods
- Support of evacuees, and documenting evacuee information
- Confirming the whereabouts and safety of residents
- Issue of Disaster-victim Certificates

The receipt and management, transportation to the evacuation centers and other locations, and distribution of the enormous volume of relief goods that poured into the affected areas from all over Japan, was time-consuming and required the intensive efforts of a large number of employees. Such tasks could usually be completed by assigning numerous people to the job, however, in municipalities with a small population size and small number of government employees, there was a wide gap between the number of people required to handle the huge volumes of relief aid items and the actual number of people who were available to help, resulting in a strenuous workload for the employees. Further, in municipalities where power supply had not yet resumed and telecommunications networks were not operational, information and communication technologies could not be used for various jobs related to the setting up of evacuation centers and creation of evacuee lists, etc., thus delaying responses. Information had to be communicated manually and employees physically carried paper documents to wherever required, indicating a major disruption of the technologically advanced ICT division office environment.

As part of business continuity planning, due consideration must be given to action that can be taken beforehand and relevant training conducted to ensure smooth implementation of the disaster response measures described above. Based on responses from the municipalities surveyed, some of the action items that can be implemented beforehand are listed below.

- Establishing and operating evacuation centers: selection of candidate sites, identifying optimal routes for evacuation and transport of goods, ensuring means of obtaining and sharing information, securing personnel, etc.

- Transport and management of relief goods: establishing structures to receive and manage relief goods, determining locations to receive goods, creating a system to verify the needs of people affected by the disaster against relief goods received, securing personnel, etc.

- Support of evacuees, and creating evacuee lists: securing personnel to aid in relief operations, making preparations to acquire replacements of ICT devices, re-install systems, etc.

- Confirming the whereabouts and safety of residents: determining procedures for confirming the whereabouts and safety of residents, securing personnel, etc.

- Issue of Disaster-victim Certificates: making preparations to acquire replacements of

ICT devices and to re-install systems, establishing information networks, determining locations for the issue of certificates, securing personnel, etc.

The initiatives that must be taken to ensure smooth implementation of disaster responses are varied, ranging from installing ICT devices and other information processing systems to securing materials for setting up evacuation centers and obtaining food as well as other relief goods, and many issues, including securing adequate personnel to manage and implement these measures, need to be addressed. Mechanisms must also be put in place to match personnel and logistical needs with provided supports. In addition, infrastructure that supports networking between diverse entities is required to provide assistance to evacuees, confirm the whereabouts and safety of residents and conduct other related tasks.

In contrast to issues that can be resolved by installing information processing systems, resident service counters, such as those for the issue of Disaster-victim Certificates, often receive a large number of applications at the same time and personnel support must be provided to deal with the workload. In some municipalities, there were days when over 500 residents queued up at the temporary disaster response counters, and municipal government employees worked tirelessly to cope.

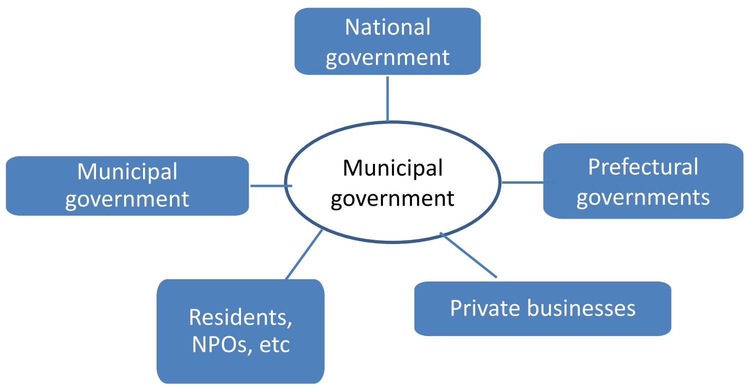
9.2 Collaboration between diverse entities

9.2.1 Diverse entities that have working relations with municipal governments

A study of the recovery processes at the ICT divisions of the 13 municipalities surveyed reveals the diverse entities that were involved and the vital roles played by each one of them. When considering the future role anticipated of ICT divisions of municipal governments, it is evident that implementing measures to handle all potential risks by the municipalities alone is impractical from the perspective of cost. Collaboration between the municipal governments and diverse entities is extremely crucial.

(see Figure 5)

Figure 5: **Diverse entities that have working relations with municipal governments**

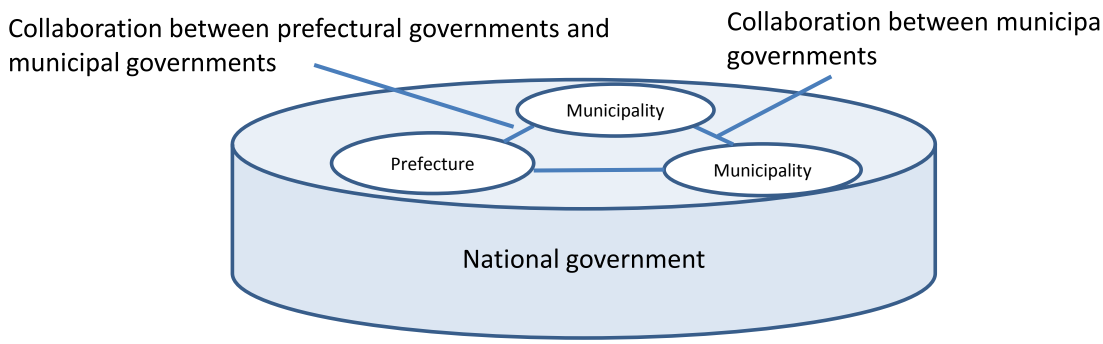


In this survey, we assume the numerous external entities that have business relations with the municipal government to be the National government, prefectural governments, other municipal governments, and private businesses such as subcontractors of information processing systems and telecommunications services, as well as local residents, NPOs and other organizations. Business relations with local residents, NGOs and other organizations are not within the scope of this survey and will not be discussed here.

It is improbable that the municipal government will always form the hub as shown in the conceptual diagram above. Based on the objective of the action being taken, it is necessary to determine the focal entity and create corresponding frameworks. Each entity must, at all times, have structures in place to ensure information sharing and uninterrupted means of communication.

With regard to collaboration between these entities, we suggest that, to begin with, they develop the concept that the National government must provide assistance in terms of funds, establishing systems and improving infrastructure. (see Figure 6)

Figure 6: Conceptual diagram on collaboration between the numerous entities



In this section, we review the role of the National government as shown in the figure above and study the creation of frameworks for mutual assistance between municipalities.

9.2.2 The role of the national government

Numerous requests of the National government were made in this survey, including regarding applications for and uses of subsidies; the development of telecommunications infrastructure in natural disasters; and the establishment of various frameworks. The action items that the national government must undertake, from the viewpoint of supporting municipalities, have been described in this section.

(1) Financial assistance to carry out measures expected of local municipalities

Supplementary national government budgets were set aside by the municipalities surveyed for restoration of ICT operational environments, however, financial assistance is absolutely necessary for the preventive measures that ICT divisions must take as part of lessons learned from the 3/11disaster. In addition to expenses for installing information processing systems to implement disaster responses, municipalities will bear other long-term operational costs such as for telecommunications infrastructure, emergency power generators, data backup, etc. Some kind of financial aid will be required for these operational costs as well. Although several financing projects have already been initiated within the national government budget for the establishment of quake-resistant telecommunications infrastructure, support for installation costs alone will not suffice and supporting projects must be provided from a long-term perspective.

(2) Assistance to establish systems

Based on the Japanese Act on the Protection of Personal Information, each municipality has ordinances and other regulations to protect personal information. However, opinions vary by municipality regarding items that are not covered by the law, and thinking on whether information on evacuees should be provided to third parties or not also differed. In the survey, some municipalities indicated the need for common policies regarding the provision of personal information to third parties when extensive devastation occurs, as was seen on March 11.

The Study Group on Maintaining Communications Capabilities during Major Natural Disasters and other Emergency Situations set up by the Japanese Ministry of Internal Affairs and Communications concludes in its final report that there is the "need for new examinations on the treatment of personal information during large-scale disasters." The committee also recommends that "municipal governments should proceed with studies of finding the right balance between the necessity of providing information on people's safety and other critical information during large-scale disasters and other emergencies and the demands of personal information protection and, where necessary, municipal governments should revise their personal information protection ordinances (such as defining exception clauses concerning the treatment of personal information in emergencies).

Taking into consideration the wishes of the municipalities surveyed, however, it is difficult for each municipal government to individually implement measures towards defining exception clauses concerning the treatment of personal information in emergencies, and hence the National government must take action such as drawing up common guidelines for all municipal governments.

With regards to the types of digital data handled by municipalities as well, different ministries process different information--for example, the ministries responsible for the Juki system and for the Family Registration system vary--and no standard policies for systems operation in the event of a disaster were created either. Standard rules must be established for all digital data handled by each municipality in the aftermath of a disaster, until normal systems operations are resumed.

Development of personnel is also an important form of systems-related support. No matter what prior arrangements are made, in some cases, it is the decisions taken by personnel at the disaster site that are most crucial. Given that similar disasters could occur anywhere in Japan, it is extremely important that the National government take measures to develop people capable of making key decisions at disaster sites.

(3) Improving electricity and telecommunication infrastructure

Incentives, including financial assistance, must be provided by the prefectural or National government to municipalities that independently take measures as part of their business continuity plans to install and operate emergency power generators. However, with regards to establishing infrastructure for commercial electricity supply and telecommunications that cannot be handled by municipal governments at either the municipality or prefectural levels, the

National government must make proposals and take nationwide action towards ensuring redundancy.

The municipalities surveyed showed keen interest in cloud computing technologies, especially as a means of data backup. In order for municipality and prefectural governments to set up private clouds as data backup sites with due consideration to security and protection of data, the National government must draw up relevant guidelines and regulations.

(4) Standardization

The shared use of information processing systems by municipalities necessitates enormous effort by each municipality, such as a review of business processes and transfer of data related to current business processes, hampering the introduction of such systems. Many of the municipalities surveyed expressed their wish for the National government to propose measures towards the shared use of information processing systems and unified methods for data transfer.

One important post-disaster task at the municipalities surveyed was the organizing and documenting of evacuee information. Survey respondents pointed out that private businesses could not speedily help with this task since the document format, the contents of information recorded and other details varied by municipality. Proactive measures by the National government are necessary to create standard document formats with consistency in items of information.

9.2.3 Creation of frameworks for mutual assistance between municipalities

The creation of frameworks for mutual assistance between municipalities may be advantageous in the event that the disaster exceeds levels assumed by the business continuity plan or disaster responses do not proceed as planned.

Specifically, although municipalities conclude agreements with each other for cooperation in the aftermath of a disaster, there are few instances in Japan of dedicated agreements between ICT divisions for this purpose and the concept must be expanded in the future.

In Rikuzentakata City and Otsuchi Town, employees from other municipal governments contributed immensely to restoring the ICT operational environments. It, however, takes a significant amount of time to acquaint oneself with systems and network environments in the disaster area and also requires appropriate technical skills. Given that personnel support is essential for relief work, how to match personnel to suitable jobs is a topic for future discussion, along with areas of support that the prefectural government must play a lead role in.

Currently, material support is considered to be within the scope of regular disaster response cooperative agreements, while personnel support to ICT divisions is not. Hence, a sense of shared awareness must first be developed among relevant authorities of the importance of personnel support.

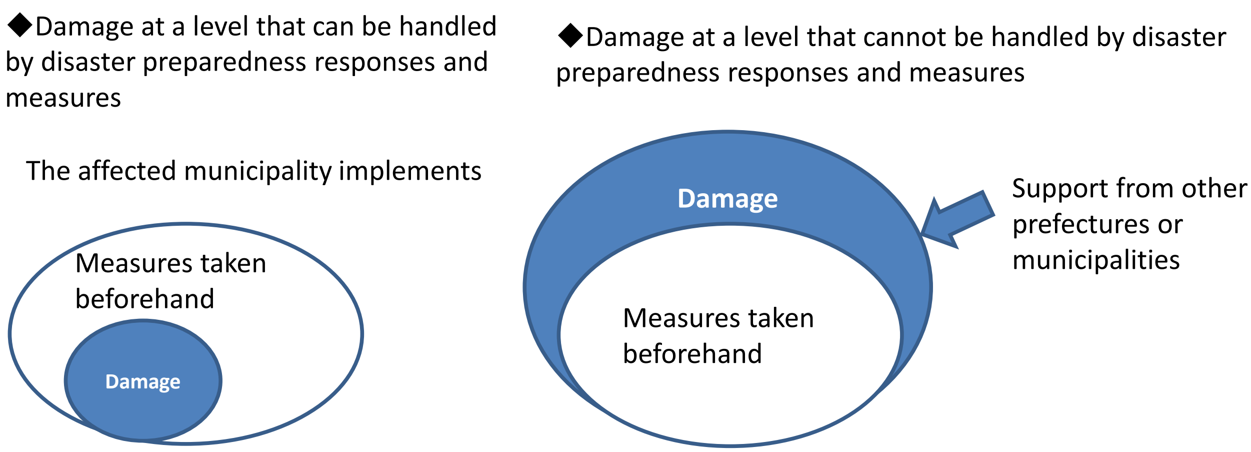
Further, as part of disaster preparedness measures should there be need to relocate government office functions, candidate sites for relocation must be determined in advance and disaster response cooperative agreements signed with the relevant municipal governments in order to enable speedy acceptance of equipment and other items necessary to conduct work.

Increased collaboration between ICT divisions of municipalities during peaceful times, with a view to improving relations and promoting the use of information processing systems, may also be effective in providing and accepting mutual support in a timely manner.

To enhance the effectiveness of support provided, survey participants suggested the creation of frameworks for mutual support between municipalities that have similar population sizes or utilize the same type of information processing systems. They also stressed the importance of collaboration with municipalities that are geographically apart to reduce the likelihood of both municipalities being struck by disaster at the same time, and of signing agreements with more than one municipality.

Figure 7 is a schematic representation of frameworks for mutual assistance between municipalities. Assuming cases in which prefectural governments support municipalities and those in which municipalities support each other during disasters that exceed levels estimated in prior preparedness plans, identifying what will be the most effective form of support is a topic for future consideration. Although not in the scope of this survey, initiatives conducted from the perspective of collaboration with administrative organizations and residents are also important.

Figure 7: Frameworks for mutual assistance between municipalities.



10. Conclusion

Based on the results of this survey, we studied the ideal state of future action by ICT divisions of municipal governments through specific measures and proposals. Our studies indicate that future measures can be divided into disaster preparedness and prior training that will certainly help cope with post-disaster risks and flexible post-disaster responses to eliminate disparities between needs that are likely to arise in a wide variety of areas and actual support received.

Many of the disaster preparedness measures can be resolved by drafting business continuity plans. These must be prioritized in order of importance and tackled one by one, keeping in mind the diverse needs of the disaster victims.

Among the measures that can be taken beforehand, office-wide discussions are necessary for the creation of data backup standards even before the drafting of business continuity plans and plans that include the creation of data backup standards must be drawn up. Further, the roles of the numerous entities that have business relations with the municipal government must be specified and measures taken to improve collaboration at all times.

With regard to flexible post-disaster responses, the development of on-site personnel is most important and reflects thoroughly implemented daily work practices that will stand in good stead during a disaster.

The scale of the Great East Japan Earthquake and tsunami was such that could not be anticipated in any business continuity plan, even if such plans had been prepared.

However, as the proverb ‘Forewarned is forearmed’ goes, it is important to draft business continuity plans that draw on this experience, deepen understanding and awareness altogether through thorough daily work practices so that the effects are reflected appropriately during an emergency.

Reference

This report is an abridged and revised (to suit foreign readers) version of a much larger report written in Japanese that contain detailed report of each municipality. The original report is as follows:

財団法人地方自治情報センター、慶應義塾大学SFC研究所、「東日本大震災における地方公共団体情報部門の被災時の取組みと今後の対応のあり方に関する調査研究報告書」平成24年3月.

https://www.lasdec.or.jp/cms/resources/content/26859/all.pdf

Appendix-3

Questionnaire for survey on securing communications during disasters

Before answering the question, please select a following disaster type being the base of your answers.

☐Earthquake ☐Typhoon ☐Others ( )

☐Never expected disasters (answer to the question with assumptions)

1. Information needed to collect

Please select information you needed to collect during the disaster that you chose above. You can select multiple items from the following table. Items should be selected based on chronological sequence (immediately after the disaster / from 2 days to 3 days after a disaster / from 3days to 7 days after a disaster).

Immediately after the disaster (within 24 hours) / From 2 days to 3 days after a disaster / From 3 days to 7 days after a disaster	□①damage situation □②condition of roads and public transportation □③safety of residents □④evacuation centers □⑤direction from national government □⑥needs of disaster relief □⑦secondary disaster □⑧prospect of restoration of infrastructure □⑨response of police □⑩situation of neighboring municipalities □⑪others （ ）

2. Channels used for information collection

Please select a channel you used for collecting information that you chose in a previous question. You can select multiple items from the following table. Items should be selected based on chronological sequence (immediately after the disaster / from 2 days to 3 days after a disaster / from 3days to 7 days after a disaster).

Immediately after the disaster (within 24 hours) / From 2 days to 3 days after a disaster / From 3 days to 7 days after a disaster	□①fire □②police □③community FM □④AM radio □⑤phone □⑥mobile phone □⑦satellite phone	⑧FAX □⑨internal network □⑩internal e-mail □⑪mobile phone mail □⑫e-mail □⑬message board □⑭internet	□⑮twitter □⑯blog □⑰SNS □⑱cars □⑲officials □⑳TV □21 newspaper □22 J-Alert

3. Information needed to transmit

Please select information you needed to transmit during the disaster that you chose above. You can select multiple items from the following table. Items should be selected based on chronological sequence (immediately after the disaster / from 2 days to 3 days after a disaster / from 3days to 7 days after a disaster).

Immediately after the disaster (within 24 hours) / From 2 days to 3 days after a disaster / From 3 days to 7 days after a disaster	□①evacuee centers □②evacuation orders □③damage situation □④condition of roads and public transportation □⑤prospect of resume of administration services □⑥prospect of restoration of infrastructure □⑦situation of neighboring municipalities □⑧status of supports from outside □⑨safety of residents □⑩others（　　　　　　　　）

4. Channels used for information transmission

Please select a channel you used for transmitting information that you chose in a previous question. You can select multiple items from the following table. Items should be selected based on chronological sequence (immediately after the disaster / from 2 days to 3 days after a disaster / from 3days to 7 days after a disaster).

Immediately after the disaster (within 24 hours) / From 2 days to 3days after a disaster / From 3 days to 7 days after a disaster	□①fire trucks □②prefectural disaster wireless □③prefectural disaster system □④public announcement system □⑤internal receiver □⑥mobile phone's mail □⑦internet email	□⑧disaster message board □⑨home page □⑩twitter □⑪blog □⑫SNS □⑬cars □⑭officials □⑮others

Appendix-4

Teaching case “Building Information Systems during the Cloud Era: Based on Lessons from the Great East Japan Earthquake”

Keio University Case Study Materials

Building Information Systems during the Cloud Era

— Based on Lessons from the Great East Japan Earthquake —

In March 2011, a major information systems company in Tokyo newly established a program (with a time limit) that enables its employees to take one day of volunteer leave per month in order to participate in volunteer work related to reconstruction assistance in areas affected by the Great East Japan Earthquake. It is now October 2012, and Yamada, who is a public sector manager for this company, has been using the program to travel to these affected areas about once every three months.

Yamada actually saw the status of the affected areas with his own eyes, and it was worse than he had imagined. The debris that had filled the roads immediately following the earthquake, as shown in television reports, had been removed, but only building foundations remained and the bare soil had become exposed. This scenery was etched into his memory. Yamada visited the affected areas several times, but did not get the impression that the recovery efforts had been progressing. Nevertheless, as if to cover up the memory of the earthquake disaster, thickly grown grasses have been turning the land into green fields as far as the eye can see.

The volunteer work that Yamada did was mainly removing debris and mud from inside remaining houses. At the worksites, he met a variety of people visiting from all over the country in order to volunteer. Among them was university researcher conducting a field study with regard to the information systems of local governments affected by the disaster.

Yamada spoke extensively with this researcher about the content of this study. He learned that the local governments that had been severely damaged were unable to use their systems following the earthquake as the result of power outages. Due to these power outages and network devices being washed away, the government personnel could not get in touch with the outside, and therefore were unable to request assistance. The coastal areas affected by the disaster had small populations, and had few personnel involved in information systems. In some cases, there were local governments whose information system personnel had been affected by the disaster. The support of private sector business operators has significantly contributed to the recovery of the affected areas. Meanwhile, many business operators have been encouraging local governments to introduce high-spec, high-priced systems, targeting the reconstruction budget of the national government.

At Yamada's company, a new project for proposing information systems to affected local governments was launched, and Yamada was selected as a project member. Yamada has been interested in building new systems that utilize the cloud. In FY2012, the "Public Cloud Promotion Headquarters" was established at his company, and Yamada became one of the employees affiliated with this department.

According to the researcher, the circumstances of the affected local governments were extremely varied, even in terms of information systems alone. Based on the lessons learned from the earthquake disaster, what type of system should be used? Such a system would surely be applicable not only to local governments, but also companies in general. Yamada recalled five cases mentioned by the researcher, as he gazed out the window of his office at people going to and from Tokyo Station.

Case (1): Lost resident record

The everyday scenery was completely transformed.

The Great East Japan Earthquake, which occurred at 2:46 p.m. on March 11, 2011, caused a massive tsunami that engulfed many towns in the Tohoku region.

At that time, the information department[i] workers of the Minamisanriku (**Appendix 1**), which is located in the northeast coastal region of Miyagi Prefecture, were inside the Minamisanriku government building, a two-story structure made of wood. They stopped by the building for a while in order to gather information, but the power was out in this building, so they went to check the server room in the disaster response building (three-story structure) next to the government building, where the server was set up. Fortunately the devices were not damaged. They moved to a disaster response headquarters that had been set up inside the government building and attempted to continue gathering information, but just then they heard a broadcast on the town's disaster prevention radio system, saying, "A six meter high tsunami has formed." Then, a second broadcast stated that the height of the tsunami was "10 meters." They evacuated to the rooftop of the building with the other personnel who were inside the disaster response headquarters. The disaster response building was less than 1 kilometer from the coastline, and a tsunami over 10 meters high approached them. The tsunami went up to the roof of the disaster response building and took everything along with it. Only the frame of the building was remaining. The wooden government building was swept away without a trace left behind.

The employees who had evacuated to the roof and survived, spent the night on top of the disaster response building, which had been turned into only a frame. The next morning they climbed down to the ground using a rope made for seaweed cultivation that appeared to have been washed in by the tsunami. A disaster response headquarters was then established in a town facility about 3 kilometers away from the government building. Apparently this facility was inundated with a group of over 1,000 of the evacuees.

The first thing they had to do was to check the safety status of the residents and identify the evacuees. They wanted to view information on the basic resident registration system that they use to manage the basic registration of residents[ii], but the servers in the server room inside the disaster response building had all been swept away, and it was difficult for the workers to even search for them. The backup servers had also been stored in the server room, so were swept away as well. Therefore, using pencils and papers that had been provided as aid supplies from across the country, they manually began the work of checking the safety status of residents.

On March 22, on the tennis courts next to the facility where the disaster response headquarters had been established, the workers set up a prefabricated provisional government building. They also installed an emergency power generator. In addition, a business operator that had commissioned to manage their information systems provided them with complete systems for issuing victim's certificates (servers, personal computers, and printers, etc.). This business operator had a basic system[iii] to back up data on March 4. Using this data backup system, they created an environment for the resumption of operations.

In Rikuzentakata (**Appendix 2**), which is located in the southeast coastal area of Iwate Prefecture, a three-story (and partly four-story), reinforced concrete government building—positioned about 2 kilometers from the coastline—was engulfed by the tsunami.

As the tsunami was approaching, the personnel who were in charge of the regional network went up to higher ground inside the city. This was partly so that the employees who were also working in the area of public affairs could take photographs to record the tsunami. As seen from the high ground, the tsunami was larger than expected. The day-to-day scenery vanished in moments. It was not possible to return the government building that had been engulfed, so the employees went to a nearby community center where they spent a sleepless night. On March 12, they ran into a town worker by chance, and heard about a disaster response headquarters facility that had been set up. This facility had started checking the safety status of residents. Lines were drawn on pieces of copy paper found inside the facility, and the names of the citizens were written on them. The power went out immediately following the earthquake, and then started to come back on in the evening of March 14, so personal computers could be turned on. Two or three employees stayed up all night inputting names, and the task was mostly completed within about a week.

About one in four of the Rikuzentakata city employees perished in the earthquake and tsunami. Some workers in charge of information systems also lost their lives. The server room inside the government building was submerged. The recovery operations related to information systems ended up being carried out by predecessors' predecessors.

On March 15, a business operator that been commissioned to manage information systems brought a paper printout of the basic resident register as of the end of February, and a CD containing the data.

On March 19, a prefabricated provisional government building was set up on private land 150 meters away from the facility where the disaster response headquarters had been set up. Around that time, the personnel who had come to be in charge of information system recovery operations, together with the manager of the business operator that had been entrusted with the information systems, headed over to the government building that had been devastated by the water. This was to recover the server hard disks, backup tapes, and so on that were still in the server racks. The group was able to successfully collect the mud-covered devices and tapes. They immediately requested a business operator to carry out salvage[iv] operations. As a result, the basic resident register system, welfare system[v] data, and tax report data were successfully restored, but the other data could not be restored. The backup tapes that were collected together with the hard disks had been soaked in water and were covered in mud, so resurrecting the data was impossible.

There was a notable shortage of workers to check the safety status of residents and implement recovery operations. As such, support workers were dispatched to the information department from Nagoya on April 22, and from Hachimantai, Iwate Prefecture on May 1.

In a similar manner, Otsuchi (**Appendix 3**), which is located in the coastal area of Iwate Prefecture about 30 kilometers north of Rikuzentakata, also lost about one-fourth of its workers in the tsunami. Its government building was located close to the shoreline and had a two-story tall concrete block structure. The building was engulfed by the tsunami. After the occurrence of the earthquake, a disaster response headquarters was set up in the open area in front of the government building, and the employees were holding a response meeting when the tsunami struck, so many workers, including executive personnel, became victims of the disaster. The remaining personnel set up a disaster response headquarters at the central community center located on high ground inside the town, and on April 25, they opened a provisional government building in the schoolyard of an elementary school adjacent to the central community center. This elementary school had been affected by a forest fire that occurred following the earthquake, so it was closed.

All of the information department workers became victims of the disaster except for the group leader. The group leader was driving to Morioka for a business trip on March 11, and immediately headed back toward Otsuchi after the earthquake occurred, but could only reach as far as Tono on that day. The next morning on March 12, the group leader saw the completely changed scenery of the town. The employee coincidentally met a town worker along the road and heard that a disaster response headquarters had been set up at the central community center. The group leader headed in that direction in order to check the situation, but—due to a forest fire had occurred close to the community center—could not make it there, and spend the night of the March 12 in a nearby evacuation shelter. The situation only became clear to the group leader on March 13. This employee learned that the workers in charge of the information department inside the government building on March 11, had taken the backup tapes for the basic resident register, family register, tax, and general welfare servers that had been stored inside a safe in the government building, when they evacuated the government building. These workers then became victims of the tsunami, and the backup tapes were not among the items that they had left behind. The server room had been set up inside the submerged government building, so the resident information was temporarily lost.

On March 25, the workers entered the server room of the government building together with personnel from Iwate Prefecture and the manager of a business operator that had been entrusted with managing information systems. The group removed the devices from the rack and found that they were filled with mud and debris. At that time, the group recovered seven basic system servers and so on (general welfare server, basic resident register and tax server, nursing care server, query and issuance server, operational server, and two financial accounting servers), and requested a hardware business operator to salvage the data inside these servers. As a result, the hard disks of the basic resident register server, tax server, and nursing care server were successfully restored, but the general welfare server could not be restored. As for the financial accounting servers that were recovered at that time, the data was restored from backup tapes that had been left behind in the server room.

On March 29, while waiting for the results of the salvage operations, the disaster response headquarters set up one provisional server for resident queries that it received at the community center[vi]. The data that it used was extracted from the host of the business operator entrusted with the basic resident register system, and was as of March 1. The hardware of the provisional server was provided by the business operator.

On April 13, using the basic resident register data that had been salvaged (as of March 11), the headquarters set up a second provisional server. As a result, Otsuchi began contact point operations. On April 25, when the provisional government building opened, the server devices were left behind at the community center, and the resident contact point and offices for workers were transferred to the provisional government building.

Case (2): Disaster response operations and systems

Around 1,000 evacuees were inundated the facility where Minamisanriku had set up a disaster response headquarters. The town hall employees were working on the evacuation shelters that had been opened up in over 30 locations inside the town. The roads to the evacuation shelters were filled with debris. During the days up to when the emergency restoration of the roads had been completed, the personnel had to take detours through mountain roads in order to get to and from each of the evacuation shelters and the town's disaster response headquarters.

On March 22, the establishment of a prefabricated provisional government building was completed. The only power source was emergency power generation equipment, but on March 28, the government resumed a portion of its contact point operations for residents, such as the issuance of certificates of residence. Information on persons affected by the disaster[vii], which was needed in order to implement contact point operations, was prepared and managed by each of the operational departments, using Excel and Access as bases.

As for the issuance of victim's certificates (see supplementary explanation on the following page), initially the government used a system that had been provided by a private-sector business operator, but with support from Nishinomiya, Hyogo Prefecture, it introduced a "victim support system"[viii] in September (with a notebook computer for the server), and put this into operation in November. The victim's certificate issuance system that had been provided by a business operator had consisted of individual systems for each operation, but each of the operational departments wanted the introduction of a "victim support system" that could be used for multiple purposes as a base for resident information (victim register). As such, the government decided to introduce such a system, because it was expecting to receive support for system revamping from Nishinomiya.

In April 2011, the information department personnel of Ishinomaki, Miyagi Prefecture (**Appendix 4**), which is adjacent to Minamisanriku, were working on preparations for the introduction of a "victim support system." The Ishinomaki government building was not significantly damaged (although its free access floor storing power cables and so on had been flooded), and it had an environment allowing for the immediate launch of Linux, so it succeeded in putting this system into operation right away. The necessary dummy (provisional) data for system operation was input during the third and fourth weeks of April, with the aim of starting formal operation of the system at the end of the May holiday. The government started issuing victim's certificates during the May holiday, and on the day prior to starting this, it discarded the dummy data and input the basic resident register information as of March 11.

After starting operation of the system, it became clear that in some instances, it was not possible to differentiate between residents living in the same condominium or other type of housing complex, and that operations in Ishinomaki were different from those in Nishinomiya—which had developed the system—with regard to donation and support fund management systems. When inputting the basic resident register, even if incorrect numbers differing from those of the system manual were input, the system would accept these, and this would cause different types of data to be output. The government workers were unable to match the data format to Nishinomiya's standards, so, while reading the manual, they asked the business operator manager—who was stationed at the government building in order to provide system support—to rewrite the shell script[ix] as much as possible. After the introduction of the system, this type of work was carried out once a week. The volume of data was large, so in some cases the browser session would time out before the calculation could finish.

There were issues in terms of operation, but implementing disaster response operations requiring the handling of resident information for a population of 150,000 people, was unthinkable.

[Supplementary explanation: local government operations in the event of a disaster]

Various types of victim support systems are applied to citizens who have been affected by natural disasters having a notable impact on basic lifestyles (natural disasters corresponding to the stipulations of the Disaster Relief Act). In order to use a victim support system, it is necessary to have a victim's certificate, which is issued by the local government with which the resident is registered. Victim's certificates provide public proof of damage to a residence. The local government receives an application from a victim, and then investigates the status of damage to the residence in question (totally destroyed, mostly destroyed, partially destroyed, or partly damaged). As such, victim's certificates are important documents that are necessary not only for various types of support systems, but also fixed asset tax reduction and exemption procedures. In order to issue a victim's certificate, it is necessary to confirm that the applicant was a resident of the region in question at the time of the disaster, that the house where the applicant was living existed at the time of the disaster, and that the house where the applicant was living was affected by the disaster, etc. After receiving applications from residents, each local government uses basic resident registers and housing registers to confirm the existence of the applicants and their houses as of the time of the disaster. Furthermore, local surveys are implemented in order to check the actual status of damage to residences. Such operations are not part of the day-to-day work of local governments, and are therefore unexpected. Local governments affected by a disaster also have a large amount of other tasks to take care of as well, such as the delivery of donation money and assistance funds, the seeking provisional housing, and the demolition of damaged buildings.

In Miyako (**Appendix 5**), which is located in the eastern coastal area of Iwate Prefecture about 100 kilometers north of Ishinomaki, the government building was submerged up to the first floor. The server room is on the second floor, so it just barely avoided being flooded (since a portion of the floor was submerged).

Miyako used the "victim support system" for the task of delivering donation money. The personnel in charge of the information department learned about the existence of the system at the end of March. The impetus for this was receiving information from a private-sector business operator. The government personnel had been gathering information via the internet, but about two weeks had passed since the occurrence of the disaster, so discussions took place inside the department, suggesting that introducing such a system at that point in time might end up causing confusion. Thus, at one point it looked like the system would not be introduced.

Then in mid-April when donation money delivery operations took place, the division chief gave the order to "introduce the 'victim support system.'" The workers requested a private-sector business operator, which is in a cooperative relationship with the business operator entrusted with the basic resident register system, to support the introduction.

Upon testing the system with a test server, it became clear that there was no data preparation function for the transferring of donation money[x]. The workers learned that there was a function for outputting the data, but the monetary amounts were not included, so the system could not be used for donation money transfer data. Therefore, the workers consulted the national support center providing assistance for the introduction of the "victim support system," and received help regarding the output of monetary amounts. Miyako possesses a mechanism for converting transfer data that has been prepared into a Japanese Bankers Association format, so it did a read-through of the data that had been output from the "victim support system," confirmed that it did not have any problems, and then prepared floppy disks to give to banks.

The building of the "victim support system" was completed in April, but it took until mid-May to establish the paperwork procedures using this system. The delivery of donation money (by bank transfer using a financial accounting system) had already been carried out three times, and using the transfer data up to that time, the workers verified that the system did not have any problems, and then used the new system starting from the fourth delivery.

As for victim's certificates, the tax department began surveys on March 12, and began issuing the documents a week later. The workers needed to take care of these certificates quickly, so they took an approach of issuing hand-written certificates and then making paper copies of these. They did not use the "victim support system" for this task.

Case (3): Development of worksites

In Kesennuma (**Appendix 6**), which is located to the north of Minamisanriku, the "One 10" government building next to the main government building was damaged by flooding on the first floor. Fortunately the server room is located in a different building, so it did not sustain any damage. The information department, which has its office inside this building, was provided a demo version of the "victim support system" by a private-sector business operator. Nevertheless, the design of the victim's certificates issued by the system did not meet Kesennuma's standards. The government expected that it would take time in order to revamp the system so that the standards could be met. The workers in Kesennuma had intended to begin the task of delivering the victim's certificates on April 18, so the introduction of the system was abandoned. Workers of the city knowledgeable about building databases created a victim's certificate database using Microsoft Access, and this was used for the job of delivering the victim's certificates. Subsequently, the worker in charge of removing debris requested a management function for collapsed building information, which the "victim support system" had. This system was built in May, and was also used for managing the removal of debris.

In carrying out disaster response operations, information systems such as the "victim support system" were effective. Nevertheless, since they were considered on an as-needed basis following the disaster, there was a lack of knowledge regarding the characteristics and application management of the systems that could be introduced. There were also restrictions on time, and as a result, governments ended up relying entirely on the business operators and so on that they had entrusted with the management of their information systems, with regard to the selection of systems for introduction.

Many local governments applied for the issuance of a "victim support system" installation key, and attempted to install this system on their server, but abandoned this idea because it did not go well, or because data processing was required in order to introduce the system.

Tagajo (**Appendix 7**), which is located in the coastal area of Miyagi Prefecture about 50 kilometers south of Kesennuma, opened a victim consultation counter on April 1, 2011. This counter was aimed at speaking with affected citizens regarding damage to residences, current evacuation shelters, contact information, and so on, and providing information about suitable support systems.

With the opening of the victim consultation counter, it became necessary to have an information system in order to create databases for information on affected persons and consultation records. The employees of the information department were told by their boss on March 27, five days prior to the launch of the consultation counter, "We need an information system for the victim consultation counter." The department frantically began researching, and considered the "victim support system," but since this system did not have a function for storing consultation records, the workers decided to develop a system independently.

The functions that they needed the system to have—based on resident information—were: the ability to record and uniformly manage consultation records; the ability to access the database simultaneously from personal computers set up at different counters in order to enable service at multiple counters; the ability to authenticate users; and the ability to use the system over a long period of time in line with the acceptance periods of the various different systems. The employees were not only lacking in time, but also money to invest in the system, so they decided to use a derivative development approach based on combining various open source software[xi].

In order to manage the consultation records at the core of the system, the workers partially customized and utilized software called "SugarCRM," which records sales activities related to customers and is used in the retail industry. This software is operated on a browser and a portion of it is provided free of charge, so the workers thought they could use it for the their intended function by narrowing down and customizing the minimum necessary elements (consulter, employee providing service, and content of consultation). As such, the employees acquired development environments from the internet such as SugarCRM (application software), PHP (programming language), MySQL (database management), Apache (webserver software), and Eclipse (integrated development environment), and then carried out development. There was no damage to the server room, so they used the existing servers inside the government building. This system is operated on a browser, so there is no need for special operations to install it on personal computers. Furthermore, since it partly uses open source software, it is license-free, and can be expected to flexibly respond to increased numbers of computers.

Operation of the system involves three steps: (1) searching for the basic information of the person visiting the consultation counter (Basic resident register data is included so the name, address, and date of birth, etc. of citizens can be searched.), (2) inputting the content of the consultation (The results of interviews with each person who visited for consultation are input. If the same person visits for consultation multiple times, information is added.), and (3) giving a copy of the consultation content to the consulter (The consulter is asked to bring the printed documents to the next consultation session. The documents are given in paper form so that the consulter can have a sense of reassurance.).

The victim consultation counter opened on April 1 as scheduled, and its system was put into operation at the same time. The workers providing service at the counter were only given an approximately one-hour briefing on how to operate the system immediately prior to the start of the counter's operations, but the first day went by without any significant problems. The employees customized detailed functions on a case-by-case basis as they operated the system.

Up to April 30, 2012, about one year after the launch of the counter, approximately 700 people, including support personnel, received consultation with regard to over 30,000 cases.

There were many local governments, such as Ishinomaki and Miyako, that revamped the "victim support system" in order to carry out disaster response operations, and local governments, such as Kesennuma and Tagajo, that built their own independent systems (**Appendix 8**).

Case (4): Expectations and concerns related to the cloud[xii]

Based on the lessons of the earthquake disaster, there have been high expectations in the affected areas related to the cloud. At the same time, many people are also expressing concerns with regard to system operation on the cloud, which is based on the premise of there being a network connection. The following are some examples of ideas related to the cloud, provided by the information department managers of six municipalities, adding Iwaki, Fukushima Prefecture (**Appendix 9**) to the five municipalities that have been covered in this case study thus far.

Miyako: "In the Great East Japan Earthquake, there were municipalities whose server devices were washed away, and this is why it seems cloud usage and remote location backups are garnering attention, but it is important to also consider the procedures leading up to when these can be used following a disaster. When using a remote location backup, it is necessary have a proper service that will put the backup data into the system, and enable it to be received in a format that can be used right away. For example, one can imagine utilizing virtualization technologies and so on, but the current situation is that there do not seem to be any services that have thought things through to that extent. As for discussions about the cloud, there are a number of aspects such as backing up data, disconnecting server operations, and cost reduction based on joint use, but there is a tendency for debates to take place mixing all of these together. I think it important to consider each element separately.

If using the cloud from the perspective of backing up data, it is necessary to take into consideration the fact that if the network becomes disconnected in a disaster, usage will no longer be possible. At this point in time, I do not really feel that shifting to the cloud is necessary. If the network becomes disconnected, even if there is a backup at a remote location outside of the city, usage will be impossible. I think if a notebook computer environment is built and network storage is connected, this would be more effective for retrieving data. We are planning to take budgetary measures for backups outside of the government offices making use of a regional intranet[xiii]. Remote location backups using the Local Government Wide Area Network (LGWAN) have been suggested, but LGWAN has a small circuit capacity, so it takes time to transfer backup data. We would prefer to prepare a circuit with a large capacity."

[Supplementary explanation: Local Government Wide Area Network (LGWAN)]

This is a network that local public bodies mutually connect to specifically for administration. LGWAN is an abbreviation for "Local Government Wide Area Network." LGWAN smoothens communication among local public bodies, serves as a foundation for the advanced usage of information based on information sharing, and enables the exchanging of information with institutions of the national government based on mutual connections with the Kasumigaseki Wide Area Network (WAN), a network for government departments, ministries, and agencies. It has a high level of security, and provides a variety of application services for administration, using an ASP (application service provider: business operator that provides application software functions via a network).

Rikuzentakata: "The reason that the national government is putting budget money toward the introduction of the cloud is that it understands that it is costly to independently introduce cloud systems at the municipal level and that introductions will not move forward. Even if the municipalities receive subsidies from the national government for initial introduction costs, they will have to cover the running costs, so the hurdles to introduction are high. Nevertheless, municipalities in coastal regions that have lost data or have taken servers out of the mud and restored them, realize the necessity of the cloud, and I believe that if the costs, including running costs, can be successfully reduced through joint usage, the feasibility of introduction will increase.

In the case of joint usage, the transfer of data is an issue. The current situation is that when registering resident information in basic resident registers, each municipality has its own unique interpretation regarding the utilization of foreign letters, abbreviations, and original characters. Therefore, it seems that rather than a resident information system—which would have high hurdles—it would be easier to consider shifting to the cloud, because it appears that operations such as financial accounting and public assistance would be relatively easy.

In the case of utilizing the cloud, it is only natural to use a highly reliable circuit, but as for the proposal of utilizing LGWAN, the line is too narrow, so I don't think it is realistic. If there are examples of municipalities actually introducing cloud systems without there being any problems in terms of security and so forth, then introducing such a system might be easier. Meanwhile, I believe that if each municipality contributes some money to construct a secure building to physically store backup data, the problems will probably be resolved."

Kesennuma: "If we carry out data storage together with multiple municipalities, this would probably be effective for reducing costs. Nevertheless, based on the current situation in which each municipality operates its own independent information system, I believe that implementing joint operation right away would be difficult.

For example, if there is a proposal to share the storage of data with other cities using LGWAN, we might be open to such an idea. Forming agreements and sharing the storage of data would be a possibility, even with the municipalities of other prefectures. The differences in operational specifications can be expected to become a bottleneck, but if we work with other municipalities that are operating similar systems, then I believe that joint operation would be more feasible. Nevertheless, in order for multiple municipalities to promote the joint use of the cloud, a considerable amount of time and effort will be required for the conversion of existing system operation policies. Operating a new system will involve running the current system and at the same time gradually switching to the new one. I am fully aware that it will not be easy to stay in step with the other municipalities in terms of operational specifications, and the timing and content of system updates.

Before using the cloud, I would like to first of all consider remote location storage, in which backup data is kept at a data center[xiv] or the like. Currently, the facilities of the business operator that we have entrusted with the management of information systems do not have circuits for direct connections, so external backups via a network are not being carried out. First of all, storing backup tapes at remote locations on a regular basis can be implemented easily, so I think that this would be a way to avoid losing all of our data even if another disaster occurs."

Ishinomaki: "I believe that the number one benefit of having multiple cities use a system is reducing costs, but rather than thinking in this way, we should use the expression 'joint usage' for the purpose of enhancing safety. Ordinarily, the safer something is, the higher the cost is, but

I believe that if we jointly use a system, we will be able to increase safety at the same time as cutting costs.

I think the problem with joint usage is that it is influenced by the sizes of the municipalities that are involved. I believe that it would be best if we implemented the system together with municipalities of the same size outside of our prefecture based on individual agreements (including BCP[xv]), etc. The talk of the cloud for local governments is getting very confusing. I think that bringing together municipalities according to population size and having them be dispersed among different regions would make for a good joint implementation environment."

Minamisanriku: "As for the joint usage of systems by municipalities, each municipality has a different way of processing operations, so it will be necessary to make a lot of adjustments in order to achieve consistency. When Minamisanriku merged in 2005, a system subcommittee was set up for each operation, and opinions were exchanged regarding work procedures and operations. I think it would be very difficult to hold discussions bringing together two or more municipalities.

Nevertheless, I believe that in the future we will probably move in the direction of joint usage and cloud utilization, taking into consideration the trend of the times and cost reduction factors. The transition process will be very difficult, so I think one approach would be for the national government and so on to designate one format, and then to make decisions on operational methods in a top-down manner.

Based on our experience of losing all of the data at our government building, including our key system data, I believe that backup data should be stored outside of the government building. The business operator that we entrusted with the management of information systems, due to a series of coincidences, happened to be in possession of our backup data. We used this data to resume our operations, and based on this background, I recognize that the problem of a backup location is a very important issue. We are also considering data storage at a location that is separate from the data center[xvi].

It is obligatory for the family register system to be established inside the government building, but a prefabricated provisional government building is not an appropriate environment for the setup of a server. We continued our operations while aware of the fact that if the temperature rises in the provisional government building in the summer, there is a high possibility that system abnormalities could occur."

Iwaki: "I feel that the remote location storage of data is necessary, but jointly using systems or shifting to the cloud does not feel right to me in terms of responding in the event of a disaster. The joint usage of systems is the idea of setting up a system in a specific location and then attempting to use this in a joint manner. If this location is struck by a disaster or some type of problem occurs, everything will come to a halt. When it comes to using the cloud, from the perspective of protecting personal information, I am concerned about the leakage of information. If we can use a closed network like LGWAN, there probably wouldn't be any problem, but I think LGWAN has problems in terms of the speed of transmissions and so on. For resident services, speed is vital, and it would not be good for us to make residents wait due to a lack of transmission speed.

From the perspective of receiving operational support from other municipalities during disasters, I think it would be great if the cloud can be utilized because of the 'commonization and standardization of operations.' If, hypothetically, the Iwaki information policy department were to sustain catastrophic damage, it would be good if operations could be handed over to a support team from another municipality, but this would require the standardization of ordinary operations, and I think there would be high hurdles. Nevertheless, the differences among municipalities are not that significant with regard to contact point operations related to support for victims, so I believe that we can probably build a system in which support operations are not difficult to carry out."

Case (5): Resumption of operations at evacuation sites

Futaba, Fukushima Prefecture (**Appendix 10**) is the local government for the sites of Unit 5 and Unit 6 of Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant. Units 1 though 4 of this power plant are located in adjacent Okuma to the south, and are approximately 2 kilometers away from Futaba.

On March 11, the information department personnel of Futaba left the government building in order to remove notices about a town council in session. As soon as they arrived back at the government building, they were hit by massive tremors. They immediately went to check on the server room. Visually there did not seem to be any damage, so they did not shut down the system (and there was no power outage at the government building). They then left the server room with intention of performing a more detailed check later.

At 8:50 p.m. on that same day, the Fukushima Prefecture response headquarters ordered an evacuation of residents within a 2 km radius of Fukushima Daiichi Nuclear Power Plant Unit 1. At 9:23 p.m. on that same day, the Prime Minister issued an order to the Governor of Fukushima Prefecture, Mayor of Futaba, and Mayor of Okuma for the evacuation of residents within a 3 km radius of Fukushima Daiichi Nuclear Power Plant Unit 1, and the indoor restriction of residents within a 10 radius of this unit. In the early morning of March 12, the national government issued an order for the evacuation of residents within a 10 km radius of Fukushima Daiichi Nuclear Power Plant Unit 1.

As of March 11, the information department personnel had placed backup tapes inside the server room. The residents proceeded west from the evacuation shelter set up in town together by car and town bus on National Route 114. The road became congested with the evacuees from towns in the area, and as a result, it took them 5 or 6 hours to arrive at the evacuation site in Kawamata, Fukushima Prefecture. Usually this journey would have taken about an hour and a half. (**Appendix 11**) The town personnel saw off the residents as they evacuated and began evacuating themselves. They had intended to return to the government building right away, so they had nothing with them but the clothes that they were wearing.

Once they arrived at Kawamata, they prepared a list of the names of the evacuees from the evacuation shelters in Futaba (11 locations), and distributed food and supplies such as blankets.

On March 19, they move to Saitama Super Arena in Saitama City. At Saitama Super Arena, 10 pairs of printers and computers had arrived from Kariwa, Niigata Prefecture, and the town personnel input the evacuee information. Saitama Prefecture provided fixed phone lines. On March 20, the business operator entrusted with the management of information systems, took to Saitama Super Arena the resident information that it had received from Futaba on March 10, as information needed for initial taxation calculations. With the help of this business operator, the workers were able to view the resident information on Excel, and while comparing the data, they began to issue victim's certificates[xvii] on that same day. Starting on March 11, the each of the operations departments carried out the processing of transfers[xviii]. Around this time, with the assistance of NTT Saitama, a disaster version of the town's website was launched.

On March 31, administrative functions were transferred to the former Saitama Kisai High School (closed in 2008) in Kazo, and operations were carried out with this site as Futaba's Saitama branch. The workers temporarily entered Futaba together with the Self-Defense Forces at the end of March and in early April. On those occasions, they picked up the devices that they needed for operations, and backup tapes that they had placed in the government building on March 12. At the Saitama branch, using these backup tapes, they launched a resident information system on a provisional server (notebook computer), and enabled the issuance of residence certificates. They also provisionally restored the family register system with the help of a business operator, based on the data that they had acquired around that time. Network building inside the branch was carried out by NTT Saitama. The network and internet inside the branch were connected in early April. Operations for the issuance of tax payment certificates, resident certificates, family register personal matter certificates, and registered seal certificates were resumed on April 18.

On April 22, the entire area of Futaba became a restricted zone.

On June 22, the issuance of victim's certificates began[xix]. The workers did not use the system, and managed the certificates with ledgers on paper. They created and managed a list of the names of evacuees using Excel starting when they were transferred to Saitama Super Arena. There was no more user-friendly system than Excel, which the workers were accustomed to using on a day-to-day basis. In order to respond in a prompt manner during the disaster, the workers thought that it would be better to have the system of one company than those of the multiple business operators that had been entrusted with the management of information systems.

On September 16, Futaba became a designated municipality under the Special Law on Nuclear Disaster Refugees.

During that same month, a network (made redundant) was connected with the data center of the business operator entrusted with the management of information systems in Iwaki, and Futaba switched from its provisional server in order to use this for operations. A server was provided by the business operator, so after this, Futaba also stored its backup data inside the data center.

On October 28, Futaba opened a Fukushima branch in Koriyama. The Fukushima branch was also connected with the data center, and Futaba carried out contact point operations, such as the issuance of certificates.

Now, as of January 2012, Futaba has still not connected to LGWAN. This is because former Saitama Kisai High School does not have a suitable location that fulfills the requirements of a LGWAN facility, and also it would be necessary to connect to a network facility in Fukushima Prefecture so circuit costs would increase.

In this same year, the Mayor of Futaba announced that the town would transfer its office functions to Fukushima Prefecture in 2013.

Namie, Fukushima Prefecture (**Appendix 12**) is adjacent to the northern part of Futaba. At 3:33 p.m. on March 11, the first large tsunami arrived at the shore of Namie. In the town, 12 evacuation shelters were opened. The power went out immediately after the earthquake, so the means of communication with the outside could no longer be used. The only sources of information were televisions and so on. Information from the national government regarding the status of the nuclear disaster did not reach the town at all.

In the morning of March 12, the Mayor, relying on information from televisions and so on, decided to evacuate residents within a 10 km radius of the Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant. At 1 p.m. on that day, the Mayor decided to transfer the town's disaster response headquarters to the Tsushima branch located in the northwest area of the town. During the evacuation to the Tsushima branch, the information department personnel took three personal computers with them from the government building. Furthermore, in order to specify persons affected by the tsunami, the workers exported the basic resident register data in a CSV format, and took this with them. They did not have enough time to take any data other than this. At 3:36 p.m. on March 12, a hydrogen explosion took place at Unit 1 of the power plant. The Tsushima branch could not use fixed telephone lines, so made use of two satellite phones that had been provided by Fukushima Prefecture, in order to make contact with the prefectural government and so on. At 3:41 p.m. on March 13, another hydrogen explosion occurred at Unit 1 of the power plant, and then at 11:01 a.m. on March 14, a hydrogen explosion also occurred at Unit 3 of the power plant.

On March 15 at 4:30 a.m., the Mayor, based on an independent judgment, decided to evacuate to outside of the town, and requested to be accepted at the adjacent city of Nihonmatsu (**Appendix 11**) to the west. At 10 a.m. on that same day, the Mayor ordered an evacuation of all of Namie, and the citizens and town personnel began evacuating to the Nihonmatsu Towa branch. The personnel took along 10 computers to Nihonmatsu: the three personal computers that they had taken from the town government building to the Tsushima branch, and seven personal computers that had originally been set up at the Tsushima branch.

After transferring office functions to the Nihonmatsu Towa branch, the workers set up a network in order to share one printer among the multiple personal computers, but the operations were carried out in a standalone[xx] manner.

When the workers temporarily went back to the government building office around March 20, they removed the family register server.

The workers started issuing victim's certificates on March 22. On April 4, they built a simple server using the backup data of the basic resident register, tax, and welfare systems that had been stored at the data center in Iwaki. Starting from late that month, they connected a network with the data center (operation type for the basic resident register, without multiplexing), and used this for operations[xxi]. The workers continued to use the simple server so that they could carry out minimal operations, such as the issuance of certificates, even if their circuit went down.

On April 22, the area within a 20 km radius of the Fukushima Daiichi Nuclear Power Plant became a restricted zone. Namie was partly included in this area.

Contact point operations were resumed in mid-April at the Nihonmatsu Towa branch[xxii].

At the beginning of May, the workers built an information-type network[xxiii] (not connected to the internet) that included a file server[xxiv]. In late May, it became possible to connect a limited number of devices to the internet. Connecting with LGWAN was scheduled for in 2012 or later.

On May 23, administrative functions were transferred to the Fukushima Gender Equality Centre located in the Nihonmatsu district.

On September 16, Namie became a designated municipality based on the Special Law on Nuclear Disaster Refugees.

Operations at the provisional government building in Nihonmatsu were resumed on October 1, 2012.

The biggest job that the information department personnel performed after the disaster was preparing a list of the names of evacuees and confirming the survivors. The workers input the name list that the citizens had written by hand at the evacuation shelter using an Excel format. They recall that when preparing the name list, they should have had the citizens also write their names in the Japanese phonetic script hiragana and their dates of birth. Checking these two types of data against the basic resident register would have been the most reliable way of preparing the name list. In actuality, the name list had many names and addresses that were written at the evacuation shelter, and in some cases, the hand-written addresses did not match with the data that the workers had brought in CSV form. Furthermore, people were moving from the evacuation shelters to the houses of relatives and so on, so the evacuation locations of citizens were constantly changing, and it was extremely difficult to specify their whereabouts.

The workers learned of the "victim support system" in April from a business operator that was entrusted with managing information systems. When workers indicated to the business operator that the town needed to be able to show both address and whereabouts data at the same time, and so on, the business operator responded that this system would not be good for fulfilling the town's needs, so they gave up on adopting the system.

The evacuation location of residents cannot be registered on the basic resident register system, so it was not possible to send out notifications related to public administration and education, etc. The server at the data center in Iwaki had originally used as a backup, so the workers were using it through the courtesy of a business operator. As such, in FY2011, the workers were planning to consider building a new information system. The worker in charge believed it is not enough for the town to store data on its own and that it should be stored in two or more places.

Appendix

Y City (**Appendix 13**), which has a population of 200,000 people and is located in the Kanto region, became subject to the Disaster Relief Act on March 11, 2011. It was spared from the region's catastrophic tsunami damage, but it faced a situation in which a power outage caused its water supply and sewerage systems to stop functioning for some time.

In around the summer of 2012, Y City was considering building an information system that could promptly provide residents with disaster information, and efficiently carry out the gathering and analysis of information transmitted by residents using SNS (social network services), such as Twitter and Facebook. Around this time, the national government was looking for local governments to entrust with experimental projects, and was considering the application of Y City.

The required functions were: uniformly managing information sent out from variety types of media on the network; analyzing this information, plotting information on maps, and visualizing relevant regions; and enabling the broadcast and distribution of information. At the same time, another issue was enhancing information reception systems, such as regional portals and signage.

The national government's budget for the experiment would only cover the cost of introducing the system, and each local government would have to cover the operation costs after introduction. The person in charge at Y City considered purchasing the system, based on the idea that it would be better to plan on investing a large amount of the budget during the first year, thereby reducing the maintenance costs later on.

The workers of Y City imagined that if they purchased the system, they could not easily handle the obsolescence of devices and adjustments to server capacity. They thought that utilization of the cloud would be the best way to respond to these issues. The government building of Y City is new—rebuilt about two year ago—so it has an environment where the cloud can be used. Above all, if the cloud had been used, it would have been possible to reduce overall costs.

Nevertheless, due to the nature of the budget, it was reasonable for the workers to take a strategy of investing a large amount of the budget during the first year, thereby reducing maintenance and management costs, so they considered purchasing the system.

They received estimates from a business operator regarding the purchase of the system, and a uniform information management system was about 14 million yen, an information mapping system was about 60 million yen, a broadcast communication system was about 28 million yen, and a system for distributing information to receiver devices was about 20 million yen. If the city had adopted this proposal, the total for the four systems would have cost 122 million yen, and including case surveys, the implementation of experiments, the analysis of results, and the development of manuals, and so on, it was expected that the project would reached about 150 million yen in terms of its scale.

Appendix 1: Overview of Minamisanriku, Miyagi Prefecture[xxv]

Area	163.7 km²
Population	17,429 (5,295 households) *As of October 1, 2010
Number of personnel	353 *As of April 2010 Information department: 3
Financial situation	FY2010 budget: 14.1 billion yen (general accounting: 7.5 billion yen, special accounting: 4.3 billion yen, corporate accounting: 2.3 billion yen) FY2010 balance (general accounting): income - 8.7 billion yen, expenditure - 8.2 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-lower (M9)
Flood ratio	52% of building sites
Death toll	565 *As of January 13, 2012
Number missing	303 *As of January 13, 2012
Number of buildings damaged (approximate)	3,330 *As of April 3, 2011
Number of evacuees	8,719 *As of April 3, 2011
Situation of affected town personnel	Dead: 33, missing: 6 *As of December 21, 2011

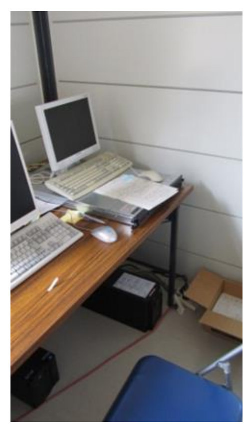
(Left: overall view of provisional government buildings in Minamisanriku, right: diagram of layout of provisional government buildings <photographed by author in January 2012>)

Appendix 2: Overview of Rikuzentakata, Iwate Prefecture

Area	232.29 km²
Population	23,300 (7,785 households) *As of October 1, 2010
Number of personnel	293 *As of April 2010 Information department: 3
Financial situation	FY2011 budget: 54.7 billion yen (general accounting: 47.4 billion yen; of this, supplemental budget of 36.5 billion yen) Reference) FY2010 balance (total of general accounting and special accounting): income - 17.8 billion yen, expenditure - 17.3 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-lower (M9)
Flood area	26% of building sites and arterial traffic sites (22% of building sites) *As of April 18, 2011
Death toll	1,881 *As of November 21, 2011
Number missing	72 *As of November 21, 2011
Number of houses affected	Completely destroyed: 3,159, mostly destroyed: 97, partly destroyed: 85, partly damaged: 27 *As of June 30, 2011
Situation of affected city personnel	Total of 68 missing or dead *As of December 21. 2011



(Left: damaged server room <provided by Rikuzentakata>, right: provisional server for a resident information system being operated in a provisional government building <provided by Nagoya>)

Appendix 3: Overview of Otsuchi, Iwate Prefecture

Area	200.59 km²
Population	15,277 (5,674 households) *As of October 1, 2010
Number of personnel	137 *As of April 2010 Information department personnel: 5 (as of March 11, 2011)
Financial situation	FY2010 balance: income - 10.9 billion yen, expenditure - 9.8 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	Designated as missing data by the Japan Meteorological Agency due to lack of measurement data, etc. (Reference: 6-lower in adjacent Nakazumacho, Kamaishi; 5-upper in adjacent Tadakoecho, Kamaishi; and 5-lower in adjacent Yamada) (M9)
Death toll	802 *As of October 28, 2011
Number missing	520 (of these, reports of death received for 466) *As of October 28, 2011
Flood area	Flooding of 52% of building sites in the town
Number of collapsed buildings	3,717 *As of December 27, 2011
Situation of affected city personnel	Total of 33 missing or dead *As of December 21, 2011

(Damaged Otsuchi town hall and government office building, photographed by author in December 2011)

Appendix 4: Overview of Ishinomaki, Miyagi Prefecture

Area	555 km²
Population	160,826 (57,871 households) *As of October 1, 2010
Number of personnel	1,800 *As of April 2010 Information department: 12 (as of March 11, 2011)
Financial situation	FY2010 budget: 109.9 billion yen (general accounting: 62.7 billion yen, special accounting: 41 billion yen, hospital business accounting: 6.2 billion yen) FY2010 balance (total of general accounting and special accounting): income - 109.3 billion yen, expenditure - 107.5 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-lower (M9)
Flood area	30% of plain, approximately 73 km² of coastal area

Death toll	3,280 *As of December 22, 2011
Number missing	629 *As of December 22, 2011
Number of affected residences	53,742 (approximately 70% of all residences); of these, 40% (22,357) completely destroyed *As of October 22, 2011

(Flooding inside free access floor of government building <provided by Ishinomaki>)

Appendix 5: Overview of Miyako, Iwate Prefecture

Area	1,259 km^2
Population	59,430 (22,509 households) *As of October 1, 2010
Number of personnel	671 *As of April 2010 Information department: 5
Financial situation	FY2010 budget: 44.8 billion yen (general accounting: 30.5 billion yen, special accounting: 14.3 billion yen, excluding public enterprise accounting) FY2010 balance (total of general accounting and special accounting): income - 45.4 billion yen, expenditure - 44.1 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	5-upper (Moichi), 5-lower (Satsukicho, Kuwagasaki, Nagasawa, Taro, Kawai, Kadomatashiro) (M9)
Death toll	526 (of these, 108 certified as dead) *As of December 22, 2011
Number missing	114 (of these, 108 certified as dead) *As of December 22, 2011
Number of damaged houses	Completely destroyed: 3,669, partly destroyed: 1,006, partially damaged: 176, inundation above floor level: 1,760, inundation below floor level: 323 *As of December 22, 2011

(Left: lobby of government building, taken at 4:30 p.m. on March 11, right: external appearance of government building after tsunami receded, taken at 12:00 p.m. on March 12 <provided by Miyako City>)

Appendix 6: Overview of Kesennuma, Miyagi Prefecture

Area	333.37 km^2
Population	73,489 (25,457 households) *As of October 1, 2010
Number of personnel	1,360 *As of April 2010 Information department: 4
Financial situation	FY2010 budget: 56.9 billion yen (general accounting: 27 billion yen, special accounting: 16.9 billion yen, corporate accounting: 13 billion yen) FY2010 balance (total of general accounting and special accounting): income - 47 billion yen, expenditure - 44.8 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-lower (M9)
Flood area	18.65 km^2 (5.6% of city area), 9.6 km^2 of urban planning area (20.5% of district area) Flood ratio: 38% of building sites and arterial traffic sites (39% of building sites)
Death toll	1,026 *As of September 30, 2011
Number missing	383 *As of September 30, 2011
Number of affected residences	25,093 (39.3% of all residences); of these, 16,438 (65.5%) completely destroyed *As of September 30, 2011

Appendix 7: Overview of Tagajo, Miyagi Prefecture[xxvi]

Area	19.65 km^2
Population	61,927 (24,708 households) *As of November 30, 2012
Number of personnel	457 *As of April 1, 2009 Information department: 5 (including 1 part-time personnel)
Financial situation	FY2012 budget: 41.2 billion yen (general accounting: 23.7 billion yen, special accounting: 15.3 billion yen, corporate accounting: 2.2 billion yen)

(Damage from the Great East Japan Earthquake)

Seismic intensity	5-upper (M9)
Flood area	662 hectare (33.7% of city area)
Death toll	188 *As of September 28, 2012
Number of affected residences	11,484 *As of September 28, 2012

Appendix 8: Examples of onsite responses by affected local government information departments (as of January 2012)

Municipalities interviewed		Example of creative responses	Date
Iwate Prefecture	*Miyako City*	Modified the National system Developed original victim support system	Mid-May Late December
	Rikuzentakata Town	Developed original system for checking resident safety using open source software	Mid-March
	Kamaishi City	Developed original victim support system	Mid-April
	Otsuchi Town	Developed original victim support system	around May
Miyagi Prefecture	*Sendai City*	Modified existing tax collection system to develop victim support system	Early May
	Ishinomaki City	Modified the National system	Early May
	Kesennuma City	Developed original victim support system with Microsoft Access	Mid-April
	Higashimatsushima City	Developed original victim support system	Mid-April
	Minamisanriku Town	-	-
Fukushima Prefecture	*Iwaki City*	Developed original victim support system	Late May
	Minamisoma City	Developed original system for checking resident safety with Microsoft Access Developed original victim support system	March April
	Futaba Town	Developed original system for checking resident safety with Microsoft Excel	March
	Namie Town	Developed original system for checking resident safety with Microsoft Excel	March

		Developed original victim support system	Late March

Appendix 9: Overview of Iwaki, Fukushima Prefecture

Area	1,231 km²
Population	342,249 (128,722 households) *As of October 1, 2010
Number of personnel	3,737 *As of April 2010 Information department: 15
Financial situation	FY2010 budget: 257.6 billion yen (general accounting: 118.6 billion yen, special accounting: 102.8 billion yen, corporate accounting: 36.2 billion yen) FY2010 balance (total of general accounting and special accounting): income - 255.1 billion yen, expenditure - 252.3 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-lower (M9)
Death toll	310 *As of December 27, 2011
Number missing	38 *As of December 27, 2011
Number of damaged buildings	Completely destroyed: 7,611, mostly destroyed: 6,821, partly destroyed: 22,727, partly damaged: 42,046 *As of December 27, 2011

Appendix 10: Overview of Futaba, Fukushima Prefecture

Area	51.4 km²
Population	6,932 (2,393 households) *As of October 1, 2010
Number of personnel	105 *As of April 2010 Information system manager: 1
Financial situation	FY2009 balance (general accounting): income - 5.9 billion yen, expenditure - 5.6 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-upper (M9)
Death toll	53 *As of January 24, 2012
Number missing	1 *As of January 24, 2012
Number of collapsed buildings	Details unknown

Appendix 11: Map of municipalities in Fukushima Prefecture

Source: http://www.fmu.ac.jp/radiationhealth/news/20130424-2.html <last accessed Jan. 3rd 2015>

Appendix 12: Overview of Namie, Fukushima Prefecture

Area	223.10 km²
Population	20,905 (7,176 households) *As of October 1, 2010
Number of personnel	180 *As of April 2010 Information department: 2
Financial situation	FY2009 balance (general accounting): income - 8.1 billion yen, expenditure - 7.6 billion yen

(Damage from the Great East Japan Earthquake)

Seismic intensity	6-upper (M9)
Tsunami	Arrival of first large tsunami at 3:33 p.m. on March 11, followed by several more large tsunamis
Town evacuees	Inside the prefecture: 13,846, outside the prefecture: 7,199, total: 21,045 *As of November 16, 2011
Numbers of dead and missing	Dead: 175, missing: 7 *As of November 16, 2011
Number of houses damaged	Washed away: 604, completely destroyed by earthquake: 29 (mostly destroyed or less damaged: undetermined) *As of November 16, 2011

Appendix 13: Overview of Y City

Area	284.07 km^2
Population	217,919 (90,504 households) *As of December 1, 2012
Number of personnel	1,761 *As of April 2012 Information department: 8 (also 2 resident SE)
Financial situation	FY2012 budget: 110.2 billion yen (general accounting: 65.1 billion yen, special accounting: 36.9 billion yen, corporate accounting: 8.2 billion yen)

(Information system-related budget amounts <FY2012>)

Office management expenses	Expenses required for the management of electronic information systems (expenses for the operation and maintenance of internal information network systems and thin client systems, rental fees for personal computers, rental fees for thin client system devices, rental fees for departmental server devices, rental fees for print system devices, rental fees for internal groupware virtualization server devices, etc.)	110 million yen
Electronic computer expenses	Expenses required for the implementation of mission-critical operations (telecommunications and transportation expenses, general computation system management expenses, resident record system repair expenses, maintenance expenses and rental fees for general purpose computer-related devices, rental fees for resident record and tax system devices, etc.)	370 million yen
Planning expenses	Expenses required for community informatization (electronic applications, website operation, etc.)	18.72 million yen
	Expenses required for the operation of information and telecommunications network systems	126.35 million yen

[i] In this case, departments that control government systems, government networks, and regional networks, etc. are referred to as "information departments."

[ii] Ledgers serve as the basis for "certificates of residence," which provide official proof of addresses. They include information such as address, name, date of birth, gender, and household, etc. as stipulated in the Basic Resident Registration Act. The task of issuing certificates of residence is a clerical job overseen by municipalities, and each local government has introduced an information system that manages the information of ledgers.

[iii] This refers to a system for operations (taxes and national health insurance, etc.) that use basic resident register information.

[iv] This is the task of restoring data that has been damaged.

[v] This is the task of restoring data that has been damaged.

[vi] In order to provide residents visiting the contact point with information related to the basic resident register system, a provisional server was set up for the temporary operation of a system, using a different device than the one that was originally used.

[vii] This refers to information related to degrees of damage related to residents and degrees of damage related to houses. This serves as basic information when various types of victim support systems are used.

[viii] This is the name of an operational system for comprehensively supporting the operations of local public bodies when an earthquake, typhoon, or other type of disaster has occurred. It was developed by the personnel of Nishinomiya, Hyogo Prefecture when the Han-Shin Awaji Earthquake disaster occurred. The main characteristic of this system is that it is based on basic resident registers, and centered on "victim ledgers" for the management of victims' evacuation locations, account information, telephone passwords, and welfare and school attendance information. In 2005, this system was renewed as a general-purpose web system run on Linux, and was made open source for local governments. It was registered in the LASDEC program library for local public body operations, so local governments wishing to introduce this system could use it free of charge simply by applying for an installation key. Following the Great East Japan Earthquake, the source code was also disclosed to private-sector business operators. Now, as of August 2012, it is built into the seven operational support systems of: "evacuation shelter-related systems," "emergency supply management systems," "rehabilitation and reconstruction-related systems," "temporary housing management systems," "bereaved family management systems," "collapsed housing management systems," and "assistance systems for persons in need of support."

[ix] Shell: This is a type of software that conveys instructions to OS (basic software) in response to the operations of users.

Script: This is a simple program that simplifies changes to machine language that humans cannot decode.

Shell script: This is script that can be directly processed by a shell. It is used when multiple processing (batch processing) is carried out.

[x] This is because at the time of the Han-Shin Awaji Earthquake disaster, donation money was delivered in cash.

[xi] This is software that can be used free of charge.

[xii] This is one type of information processing format in which small computers are connected to numerous networks, virtualization technologies are used to make it appear to users as though there is single computer, and data and applications are stored on the network side, in order to enable operation by users on the terminal that they have at hand.

[xiii] This is a network specifically for connecting public facilities (such as community centers) within a region.

[xiv] This is a facility specializing in the installation and operation of servers, telecommunication equipment, and so on.

[xv] Business continuity plan: This is an advance plan stipulating necessary actions and restoration targets with regard to the continuation of business operations in the event of a disaster or accident, etc. In the case of public administration, rather than a "business" continuity plan, it is referred to as an "operational" continuity plan.

[xvi] In Minamisanriku, a data center system was adopted following the move to a provisional government building.

[xvii] Rather than certificates proving damage related to buildings, these are certificates related to individuals.

[xviii] This is the operation of updating data.

[xix] The level of earthquake damage could not be confirmed onsite due to the establishment of restricted zones in response to the nuclear disaster, so certificates were issued as of June 22 proving the impossibility of inhabitation and business activities over a long-term period.

[xx] This refers to processing with a device alone, without having a connection to other computers.

[xxi] Namie had adopted a data center system prior to the disaster.

[xxii] Five branch offices had already been opened at Fukushima, Motomiya, Kori, Iwaki, and Minamisoma.

[xxiii] This is a network for sharing files and so on with the network that is being used for key operations (key network). It is common to run this network theoretically separating it from the key network.

[xxiv] This is a server for sharing files on a network.

[xxv] Appendix 1 through 6 and 9 through 12 are from the report "Investigative study concerning initiatives by the information departments of local public organizations during the Great East Japan Earthquake disaster and future response measures."

[xxvi] From the Tagajo website (http://www.city.tagajo.miyagi.jp/index.html), as of December 2012.