How geeks responded to a catastrophic disaster of a high-tech country

Rapid development of counter-disaster systems for the Great East Japan Earthquake of March 2011

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ABSTRACT

A devastating earthquake hit Japan on March 11, 2011. A history of frequent and powerful earthquakes in the region, especially the great Hanshin-Awaji earthquake of 1995, led the country to develop disaster relief methods in preparation for such natural disasters. Nevertheless, the earthquake and following tsunami destroyed much of the coastland, and caused panic, due to the Fukushima-daiichi nuclear power plant accidents. During this situation, some of the crisis-management systems performed as expected. However, the poor performance of the others required system developers to implement new and improved counter-disaster systems *on the fly*. Such systems include the nationwide refugee locator, relief supply matching system, planning applications for scheduled power outages in the metropolitan area, twitter-mining systems for realtime monitoring of public transportation systems, etc. After the disaster, we conducted a comprehensive survey of such systems, in order to record how geeks in the high-tech country responded to such a national crisis. The analysis of the resulting list of counter-disaster applications gave us useful insight for future disasters: i) authorities are advised to disclose statistical information as quickly as possible, ii) coordination among developers must be provided, and iii) interconnection of databases is essential for efficiency.

Keywords

Disaster response; Software development; e-Government

1. INTRODUCTION

A devastating earthquake hit Japan on March 11, 2011. The country has frequent earthquakes, and thus the society has prepared for such disasters, particularly after the great Hanshin-Awaji earthquake in 1995. Nevertheless, the earthquake, followed by extraordinary tsunami, destroyed a broad swath of the coastland, and caused a chaotic situation in the entire country due to the Fukushima-daiichi nuclear power plant accidents.

In the situation, some of the crisis-management systems performed as expected, such as the early alert system for earthquakes. However, other systems proved to be disappointing, such as the radioactivity forecasting system, and thus ICT (Information and Communication Technologies) developers took numerous actions to develop appropriate counter-disaster systems *on the fly*.

After the disaster, the authors performed a comprehensive survey of these systems, which resulted in a list of counter-disaster applications and computer systems developed for the earthquake. In this article, we analyze the list to clarify the conditions which motivated the developer community and facilitated utilization of their products in the aim of gaining useful insight for future disasters.

The rest of the paper is organized as follows. In Section 2, we outline the events of the disaster in order to show the state of the country after March 11. Section 3 outlines the development efforts and methodology of our survey, which is followed by case studies of representative systems. In Section 5, we discuss the ad-hoc development of counter-disaster systems by volunteer engineers. In Section 6, related works are summarized, and we conclude the paper in Section 7.

2. THE GREAT EAST JAPAN EARTHQUAKE

2.1 The Disaster

On March 11, 2011, at 14:46 JST, an earthquake of an unprecedented 9.0 Mw magnitude occurred under the ocean near the northeast coast of Japan. The resulting tsunami surged the coastal regions of north eastern Japan and flowed far inland, up to 40.5m above sea level

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at maximum, which devastated the towns, the fisheries, and the social infrastructure. The tsunami was followed by severe fire outbreaks in some cities, which further ruined the area. Over 270,000 buildings were damaged or destroyed, more than 400,000 people were forced to evacuate, and the disaster claimed over 20,000 casualties. Economical damage amounted up to an estimated 16 trillion yen at a minimum [2]. The earthquake also damaged the public transportation system of the Tokyo metropolitan area, which caused more chaos in the capital.

2.2 Nuclear accidents and their aftermath

Indeed, direct casualties by the earthquake was limited to the areas close to the seismic center. Most of the losses were from the subsequent tsunami, which also damaged the nuclear power stations. Right after the earthquake, the reactors automatically took preventative measures by inserting their control rods to stop further reactions, however, the reactors' necessary cooling units and other vital mechanisms were destroyed by the tsunami. This resulted in the unfortunate explosions in the reactor buildings, which caused radioactive fallout in a broad area of northeastern Japan. These nuclear accidents and physical damage to other power plants caused severe shortages of electricity during March. Tokyo Electric Power Company (TEPCO) and the government announced mandatory power-cutoff rotations, starting from March 14. Such a scheduled outage had not taken place since World War II in Japan, and so caused considerable confusion in the society. The power shortage continued even after the mandatory cutoff in March, and was made worse by anti-nuclear movements that urged the government not to resume operation of the nuclear power stations in the entire country.

2.3 Disaster relief systems at work

Due to the history of deadly earthquakes in Japan, the government has prepared various systems for disaster relief. Such systems include Earthquake Early Warning (EEW) [8], SPEEDI (System for Prediction of Environmental Emergency Dose Information) [18], and EMIS (Emergency Medical Information System) [13]. EEW is a system to alert the country about incoming seismic waves before their arrival. The alert is sent to TV broadcasts, cell-phones, transportation services, and other systems, in order to allow people to prepare appropriately. SPEEDI is a prediction system for radioactivity diffusion, toward rapid assessment of pollution in the surrounding areas of the disaster site. Although the system has been designed for this kind of situation, it could not announce its prediction because of the power outage and of other factors [17]. EMIS is a system for exchanging information about hospitals, their beds, patients, and departments in emergency situations. This system has the potential to appropriately match available medical resources to the needs of the people in such a disaster situation. However, the physical damage to optic fibers under ground caused disconnection of the communication networks needed for information exchange. Wireless services also stopped functioning due to damage to their base stations. Indeed, the system mainly targets medical centers with counter-disaster facilities but it was unable to accumulate information of smaller hospitals in the disaster-area, although the system was finally utilized for coordination of nation-wide transfer of victim patients.

2.4 Volunteer developers

These systems were designed for counter-disaster operations, however, various unforeseen events occurred that inhibited their correct functioning, as we suggested in a former study [15]. For example, in the first few days of the disaster, very little information was delivered from the damaged cities on the coast line via traditional media. Instead, information was transmitted from the effected areas through SNS (Social Networking Services), such as Twitter [19], Facebook [3], and Mixi [14], a leading Japanese SNS service. People with Twitter and Facebook accounts voluntarily exchanged information from various sources, and some others compiled the information on Wiki systems. These efforts gradually revealed the frightening and miserable situations in the region, which motivated many system developers and computer engineers toward implementing ad-hoc systems for counter-disaster activities in order to relieve the victims in the disaster area and to complement the existing systems for people in the metropolitan area.

3. RAPID DEVELOPMENT OF COUNTER-DISASTER SYSTEMS

3.1 Developers and Situations

The development of counter-disaster systems was facilitated by Twitter and many developers used their twitter account name for their contact points. This seemed a reasonable choice in the early phase of the disaster because many services became unstable due to the earthquake and the following power shortage. Twitter provided a relatively stable communication infrastructure to the developers, to the users, and sometimes, to the refugees. They also utilized a Twitter mechanism, called "hash-tags", which classifies their short messages. Some of the discussions produced actual counter-disaster systems, and others grew into projects with actively working members. The most notable attempt was "Hack for Japan", led by Google evangelists and other IT leaders in the country [7], which aimed to provide opportunities for exchange of ideas and for discussion of system development.

3.2 Registry of counter-disaster systems

In this manner, a variety of counter-disaster systems have appeared during the time after the disaster. To record the developers' activity, we started collecting release announcements on Twitter. Then, as the number of systems increased, we utilized summaries of developed systems on the web that were compiled by volunteer editors for a certain set of applications, such as electricity forecasting services. Whenever we found a new product, we recorded the system on our registry, utilizing a cloud spreadsheet service by Google. However, such a primitive study is very incomplete. Consequently, we searched for blogs and articles on commercial sites about useful systems for post-disaster lives in order to ensure completeness of our data. For further reliability of the survey, we retrospectively verified the release date and reachability of each service by checking realtime-search of Google, and by accessing each site. We also traced tweets of system developers on their twitter account to confirm the release date. For corporate services, we also checked their press release in order to identify their official release date.

3.3 Summary of survey

We detected 162 counter-disaster systems for the earthquake, which include 37 systems with unidentified release date (Table 1). In general, a trigger event in the real world initiated development of systems for a certain purpose. For example, applications for power-outage and power-saving were developed after the mandatory power-outage declaration and energy-save order by the government, which summed up to 51 systems in our repository. Another illustration was transportation planning applications. In these cases, the earliest systems were immediately followed by similar applications in the domain. Chronological summary of the release dates is presented in Figure 1. Note that the figure includes only applications with confirmed release dates. In March, the systems totaled up to 103, which far exceeds the statistics for April (14 systems), May (4 systems), and June (4 systems). Most systems were developed and released in March, and 66 systems were released within a week of the earthquake. The number of releases declined afterwards.

3.4 Diversity and its cost

Table 1 shows a variety of systems that met the needs of the Japanese population, but it is important to note the number of systems that share a purpose. Google Person Finder [4] is an illustrative case: the service became a dominant search engine for missing people, but still, similar systems appeared. Radiation monitoring systems were also in great demand, particularly for households with children. There were also systems for niche solutions. An illustration is a time signal radio: in order to substitute a base station for time signal radio which was suspended by mandatory evacuation, engineers released applications that mimic the synchronization radio signal with personal computers. Because of the number of released systems, we classified them by the main objective of their services. Note that these categories did not gain equal popularity. Some became indispensable, while others were ignored. The latter case sounds harmless because the developers may simply abandon their development, but this wastes the developers' precious time and spoils their motivation. Competition with similar products could also waste social resources by segmenting the users, which is disadvantageous for the growth of the application category. In the next section we examine the representative cases.

4. CASE STUDIES

4.1 Google person finder

Google, a top innovator in the Internet era, has a world-wide project for crisis response named "Google Crisis Response", which was operated during several recent disasters. Right after the earthquake hit Tokyo, engineers in their Japanese office initiated the response program to start up a variety of web services for crisis management, coordinating with Google engineers around the world. The first service they released was the Google Person Finder [4], which is a simple database service that stores missing person information, as well as information of identified people. GPF system users can search for a missing person in the database, or may register the person when confirmed alive (or dead). Google coordinated with local governments in victim areas in order to raise awareness for their services, and they also requested press companies (on Mar 16) and cell-phone carriers (on Mar 17) to share their refugee databases. These efforts confirmed their dominance in the market of people search, which was of great need in the early phase of the disaster.

4.2 Traffic / Road information

Japanese streets and roads are known to be clean and well-maintained. Nevertheless, the earthquake and tsunami devastated the traffic infrastructure of the seaside areas. Damaged roads obstructed transportation of emergency vehicles and vital supplies. An ordinary approach in such a situation is to deploy reconnaissance flights and spy satellites, to capture a complete image of the affected regions for further assessment and planning. Although the information is valuable to the headquarters, it cannot guarantee successful transportation along the entire path. Accordingly, the renowned automobile manufacturer, Honda, disclosed GPS (Global Positioning System) records of their intelligent car-navigation systems [6], and Google visualized the trip records of Honda cars on their Google-map service. The service

ID	Group name	#	Date	Examples
1	Electric Power information tools	51	03/12	Electricity Forecast
2	Radioactivity information systems	14	03/15	Microsievert net
3	Relief supply matching systems	11	03/12	Volunteer Platform
4	Integrated Information Web sites	11	03/11	Google Crisis Response
5	Medical Information tools	10	03/11	Disaster Dialysis Network
6	Smart-phone applications	9	03/16	Person finder for iphone
7	Tools for disaster victim information	9	03/11	Google Person Finder
8	Tools for Twitter	9	03/12	Machi-tweets
9	Integrated GIS systems	7	03/11	Earthquake Tohoku area in Japan 3/11
10	GIS tools for traffic information	6	03/14	Automobile trip record map
11	Other Information Web sites	5	03/16	Japan Quake Map
12	Pet Information Web sites	3	03/13	Animal Finder
13	GIS tools for Shelter Information	3	03/12	Emergency feeding stations map
14	Traffic information tools	3	03/14	A page for commuters
15	Evaluation Support tools for refugees	2	03/20	Project for baby evacuation
16	Public administration systems	2	04/12	Reconstruction support, Japan
17	Volunteer Information	2	04/25	Volunteer information API
18	Tools for Radio Clock Synchronization	2	03/28	JJY simulator for radio clock
19	Information on National Capital Region	2	03/11	Shelter map of Tokyo Metropolitan area

Table 1: Summary of system categories

provided accurate and up-to-date information of the road conditions in the entire region, which resulted in improvement of vital logistics and volunteer services in the coastland.

4.3 Relief supply matching systems

The refugees in the disaster areas not only lost members of their family, but also their city halls, retail stores, power lines, waterwork systems, etc. The Japanese Self Defense Forces (JSDF), coupled with United States Forces Japan (USFJ), immediately started rescue operation in the vast Tohoku (North-Eastern Japan) region. However, as life in shelters continued, emergency supplies turned out to be insufficient for the reconstruction of homes and villages. Accordingly, many developers decided to provide matching systems for the demands and the voluntary suppliers. Indeed, the first primitive “matching site” was released on day 2, which was a reuse of an existing matching service [1]. The next site in our records appeared on day 7, though few refugees utilized the service [20]. Thereafter, more sophisticated sites were released, which gained more popularity [21]. Another illustration was matching systems for volunteers that were used by refugees to request volunteer assistance. One of the matching systems cleverly incorporated a mapping service in order to avoid over-concentration of volunteers, however, few people utilized the service, while more popular sites attracted many users. Lack of interconnection between systems limited their market.

4.4 Electricity Forecasting Systems

Although the safety system successfully stopped the nuclear power plants in Fukushima by inserting control rods in the reactors, the tsunami damaged much of the vital equipment in the nuclear plants, and TEPCO feared a shortage in electricity even before they lost the reactors due to critical explosions. Accordingly, the Japanese government requested that citizens voluntarily limit their power usage, and later scheduled power-cutoff rotations. Accordingly, TEPCO started to disclose the usage of electricity and supply capacity on their homepage, in order to aid in the saving of power. At first, the information was provided only in graphs. Aggressive programmers subsequently released an API (Application Program Interface) to parse the graphs for numeric data of power consumption, and a variety of applications were developed utilizing the API (Table 2). Unfortunately, the data source was updated only once an hour, which may cause some delay in the alerts. To address the issue, some developers implemented estimation algorithms that predicted the usage data during the delay. These forecasting systems became quite popular in the Tokyo metropolitan area.

4.5 Radioactivity monitoring systems

The explosion of the Fukushima-daiichi nuclear power plants diffused radioactivity throughout eastern Japan, though the concentration is considered to be negligible for most areas. Nevertheless, to prevent unnecessary exposure to radiation, particularly for children, radioactivity monitoring systems were in great demand. Consequently, many groups attempted to provide contaminant maps based on the monitoring sources that were released by Ministry of Education, Culture, Sports, Science and Technology (MEXT), local governments, and

ID	System name	Author	Date
1	Yahoo! Scheduled power-outage information	Yahoo! JAPAN	03/13
2	Power-save game "#denkimeter"	TwitterID:@hiyokoya6,@hitabataba	03/14
3	Power-outage search API	TwitterID:@nyatakasan	03/19
4	TEPCO juyo.gif to CSV	TwitterID:@sqm	03/22
5	Chrome extension for TEPCO consumption	Yoshiki Takeoka	03/23
6	TEPCO power usage Bot	TwitterID:@touden_now	03/23
7	NERV confidential - power consumption	TwitterID:@Molokheiya	03/23
8	Bookmarklet for power usage conversion	TwitterID: @soc_acc	03/23
9	TEPCO power usage API	TwitterID:@kansai_takako, @itomasa	03/23
10	Electricity Forecast for Chrome 0.1.0	TwitterID:miya0001	03/24

Table 2: Electricity forecasting systems (extract)

voluntary citizens. Since the output of Geiger counters is not intuitive for ordinary people, most of the systems visualized the monitored values on graphs, and on public GIS (Geographic Information System) systems [22]. Some of the systems targeted web browsers on PCs while others were released on smart-phones in order to meet various needs.

5. DISCUSSION

Preparedness for natural disasters is essential in order to avoid preventable deaths, loss of private property, and public infrastructure. Nevertheless, even with the best preparation, unpredictable events and problems may happen in a disastrous situation. In our case, the magnitude of 9.0 exceeded the assumption of most authorities. The succeeding tsunami with 40.5m height also surpassed the estimation, which even destroyed embankments that were specially built for tsunami disasters. The worst was, undoubtedly, the explosion of the nuclear plants and the radioactive fallout, which now covers a vast area in north-east Japan. For these unexpected situations many developers contributed their expertise for rapid development of counter-disaster systems, as illustrated in the previous sections. This was an encouraging story even during the tragedy. The developers demonstrated a novel form of off-site volunteers that substantially contributed to the disaster response.

These activities were supported by several factors. An illustrative case is electricity forecasting systems. To prevent power-failure by excess consumption of electricity, TEPCO released a graph of power consumption, and later, files in CSV format, which led to applications for energy saving. In this regard, continuous data feed by authorities facilitated development of related systems. Another factor was donation of system resources, such as virtualized servers, DNS registration, etc (Table 3), which relieved operational cost of the systems. Further, free application services such as Google Sites, Docs, and Maps favored various activities of developers and were used as user interfaces for systems. Particularly, Google Maps served a key role in many systems.

Although the rapid development produced a variety of systems, they also raised unforeseen issues. First, they sometimes released systems with very similar functionality by independently developing systems for a common need. For example, there emerged five twitter Bots that tweeted energy consumption of the metropolitan area, which is a waste of effort and resources. In the case of Relief supply matching systems, similar services could also confuse voluntary donors. This also confused the refugees who posted requests for donations, because there were too many choices to make. Second, some skilled developers released sophisticated services, while others were very primitive. This leads to natural selection of services, which wastes the development resources of unselected services. If the loser spent considerable amount of time and labor toward dominance in the market, the loss could potentially be substantial. Third, independence of services may cause segmentation of information, which may spoil usability of each system. This is particularly true for matching systems.

Because of the time constraints for the release of a service, most applications were developed by small groups without coordination among them. The independence favors flexibility, which was a key for rapid development. However, this is disadvantageous for scalability. Google Person Finder, on the other hand, evolved with coordination among authorities, who had refugee and casualty information. The number of registered people reached 590,000, on Mar 29, which is the number of total refugees. Because of the data volume, GPF became the dominant service in the application category, far exceeding similar services. The centralization of information contributed to avoid waste for developers and users.

6. RELATED WORK

This section surveys recent disasters and utilization of information technology in their response.

6.1 Hurricane Katrina (2005)

Hurricane Katrina was a massive hurricane that damaged the south eastern part of the United States in 2005. At that time, blogs were a major part of social media. Macias [11] suggested that the hurricane

ID	Category name	Representative donners
1	CDN service	WIDE project, Akamai, CDNetworks, etc.
2	SSL certificate	Crosstrust, Inc., VeriSign Japan, etc.
3	SAAS	Google, Hewlett-Packard Japan, Softbank telecom, etc.
4	VPS	Sakura Internet, IIJ, NEC Biglobe, etc.
5	Application	Microsoft Japan, SoftEther, Cybozu, etc.
6	Communications	NTT communications, FON, Livedoor, etc.

Table 3: Donation list of system resources (extract)

was the first disaster where blogs were widely used for the exchange of related information. Such information included rescue, missing people, support, community formation, and damage. Most of the informants were off-site supporters. This suggests that in 2005, individuals could support disaster relief operations through information exchange. Laituri and Kodrich also reported that the Internet made disaster support possible for individuals, not solely for specialists, from this disaster [10]. Interestingly, developers utilized the Google Maps API [5], which was released only 2 month before the hurricane crisis, to build flood and damage information maps. This indicates that developers are following technical trends, and adopt new technologies for their services, if they are useful.

6.2 Haiti Earthquake (2010)

In January 2010, a gigantic earthquake occurred in Haiti. Haiti is the poorest country in the region, and the government could not provide sufficient information for rescue specialists. Accordingly, off-site volunteers helped web-mapping of available information on OpenStreetMap and Google Maps. Note that in the case of Hurricane Katrina, they mostly used blogs, which cannot easily handle geographic information. In this disaster, on the other hand, they exploited GPS features of cell-phones coupled with SMS and Twitter, in order to map various information on public GIS services [12]. The Haiti Earthquake was believed to be the first disaster where volunteers made most of the web APIs, public GIS services, and social mediums. Zook et. al analyzed how web-mapping services, such as Ushahidi and GeoCommons, were used in the Haiti relief effort [23]. Kawasaki analyzed the volunteer communities on the net that supported rescue operations at the disaster sites [9].

6.3 Canterbury Earthquake (2010, 2011)

Because Haiti was a developing country, where communication and computing infrastructure was poor, geographical mapping and other information processing were outsourced to developed countries, like the United States. Hence, disaster response by system developers was not reported in this case, and the authors looked for recent disasters in a more developed country. The earthquakes of New Zealand in September 2010 and February 2011 looked like promising cases in that regard, but, web-mapping volunteers since the Haiti earthquake was still the dominant form of off-site volunteers, except for the Christchurch Quake Map, which summarizes seismic information [16].

6.4 Summary

In a crisis situation, developers make full use of available resource and technology, within the limit of their time constraints, to relieve refugees and their supporters. The Google Maps and Twitter APIs facilitated development of new services on the web. Since 2005, web-mapping services have become indispensable for disaster response, however, as we pointed out in the Section 4, competition among individual services may waste precious resources in a crisis situation. Additionally, there are still concerns for unauthorized informants. No research targeted on these issues was found in our literature survey.

7. CONCLUDING REMARKS

As illustrated throughout the report, a great number of volunteer engineers developed various systems for the disaster, which was motivated by the real needs of people and by a firm sense of mission. Power outages cause serious harm, damaging the economy and threatening the life of hospitalized patients. To avoid such a scenario, electricity forecasts could be effective tools. Information of radioactive fallout was also in great needs for the safety of children. This motivated developers to survey the radiation level at thousands of monitoring points, to detect unnatural hot-spots (highly contaminated areas), and to visualize the hazards in an easily accessible form. Once their tools were released, developers received lively responses from Twitter, Facebook, and Mixi, which again, motivated them to continue developing disaster relief solutions. This feedback and the appreciation of users also served as an incentive for the developers.

However, our analysis suggested that the motivation of the developers was necessary, but not sufficient, for successful development of usable systems. First, even with a sense of mission they cannot simply implement services without necessary information, as exhibited in the electricity forecast systems; unless TEPCO supplies the consumption data, even the brightest programmer could not have developed an application. Secondly, once the prerequisite was met, independent developers addressed similar problems, leading to excessive diversity in the services. This was unfortunate for everybody because of the wasted developers' time and the inconvenience of the users. The wasted time could have been spent on another project, which might have had greater demand. Lastly, diversity of independent systems led to dispersion of information and serious inefficiency, particularly for relief supply matching systems.

This suggests several lessons for the future. Authorities are advised to disclose statistical information as quickly as possible in a standardized, machine-readable format. Even if handwritten data are the only available source, they should release the data in a standardized file format so that engineers can develop systems that help with manual conversion of the data by off-site volunteers (cloud-sourcing). Secondly, coordination is an essential part of system development for avoiding redundancy in the systems. In this regard, some authority might play the coordinator role, as is the case with Hack for Japan, by maintaining a registry of ongoing projects. Last, efficiency of matching systems should be improved through integration of databases (centralization), use of standardized exchange formats (decentralization), or topic-based classification of systems (segmentation), depending on the characteristics of the target domain. For all of the counter-measures, governmental commitment may facilitate the process by granting appropriate authority.

In the Great East Japan Earthquake, the Internet enabled unprecedented style of volunteers: off-site development of counter-disaster systems. The rapid development of ad-hoc systems greatly assisted in the disaster relief operations. However, the novelty of this type of activities and the magnitude of the disaster led to some inefficiency in development efforts and relief operations. We believe that the both experiences hold valuable lessons for future direction of disaster preparedness and emergency management with the Internet.

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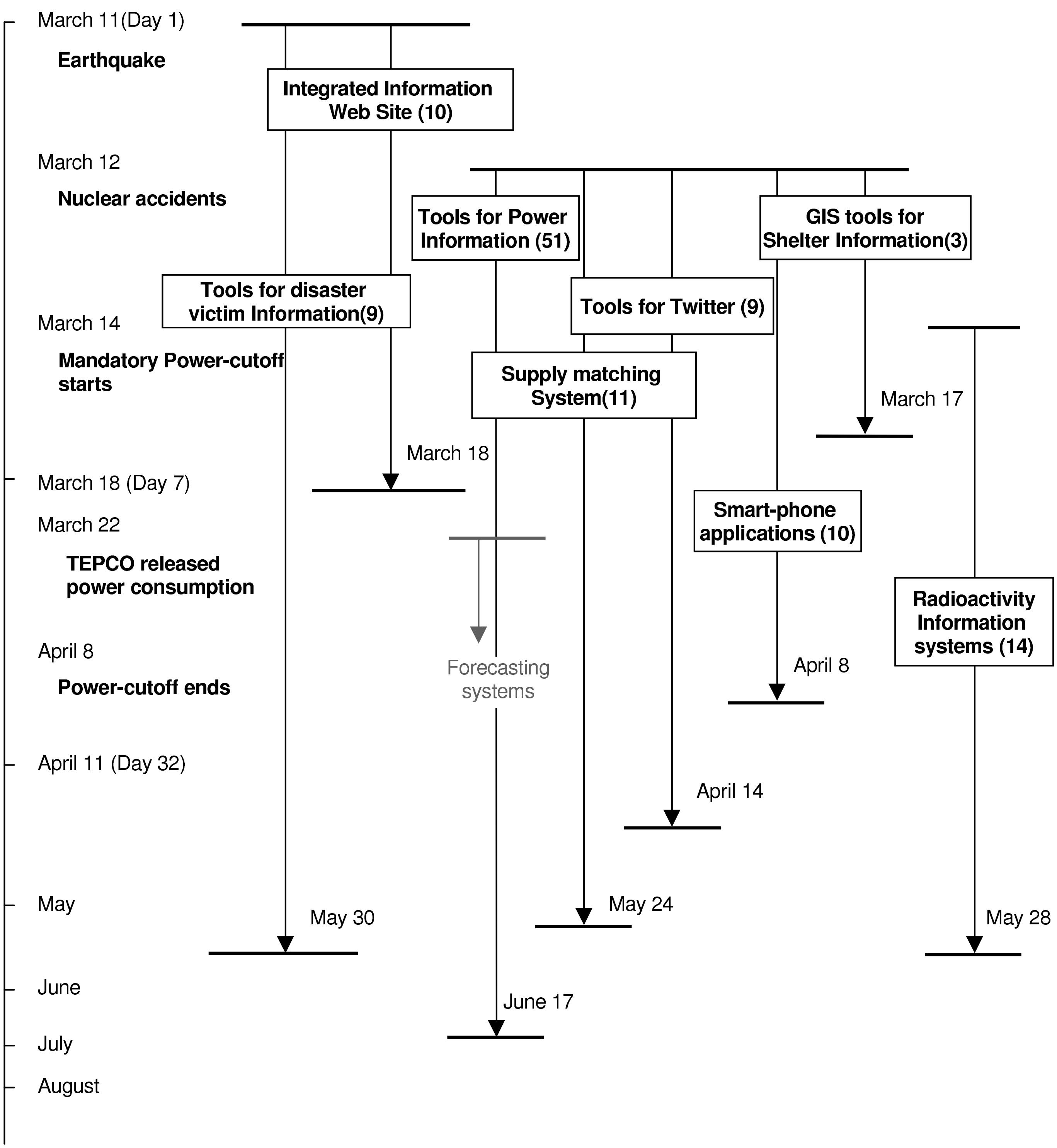

Figure 1: Chronological summary of events and developed systems