Barriers to Predictive Analytics Use for Policy Decision-Making Effectiveness in Turbulent Times: A Case Study of Fukushima Nuclear Accident

Akemi Takeoka Chatfield
School of Computing and Information Technology
University of Wollongong
Wollongong, NSW, Australia
akemi@uow.edu.au

Christopher G. Reddick
Department of Public Administration
College of Public Policy
The University of Texas San Antonio
Texas, USA
chris.reddick@utsa.edu

Abstract

Predictive analytics are data-driven software tools that draw on confirmed relationships between variables to predict future outcomes. Hence they may provide government with new analytical capabilities for enhancing policy decision-making effectiveness in turbulent environments. However, predictive analytics system use research is still lacking. Therefore, this study adapts the existing model of strategic decision-making effectiveness to examine government use of predictive analytics in turbulent times and to identify barriers to using information effectively in enhancing policy decision making effectiveness. We use a case study research to address two research questions in the context of the 2011 Fukushima nuclear accident. Our study found varying levels of proactive use of SPEEDI predictive analytics system during the escalating nuclear reactor meltdowns between Japan's central government agencies and between the central and the state government levels. Using the model, we argue that procedural rationality and political behavior can be used to explain some observed variations.

1. Introduction

Using information effectively in policy decision-making under normal conditions faces added complexity from various internal and external factors: (1) datification in government, (2) the rise of big data in government characterized by volume (scale of data), variety (different data formats), velocity (streaming data) and veracity (uncertain data quality), and (3) technological drivers such as social media platforms, mobile computing, and cloud computing in government. Moreover, policy makers in many countries face greater complexity in making effective use of information for policy decisions to produce desired policy impacts in turbulent times in high-velocity external environments, in no small part due to natural disasters and man-made disasters such as mass international movement of refugees, urban terror attacks, oil spills and nuclear accidents [11, 12, 20, 39, 55].

In the private sector, which faces not only turbulent but also competitive decision environments, big data, business intelligence, and business analytics have been increasingly adopted and used to enhance organizational, analytical capabilities such as organizational memory, information integration, insight creation and visual presentation [43], managerial decision-making effectiveness [10], organizational performance [30, 44], and supply chain performance [51, 56]. In contrast, while the use of big data [21], business intelligence, and business analytics tools by large-size local governments in the U.S. has been studied for enhanced public services in the e-government field [13], there remains a relative lack of knowledge and understanding about effective business analytics use in a policy decision-making context in turbulent times.

Therefore, this paper aims to explore the following two inter-related research questions: (1) *How does government – policy experts and decision makers – use information produced by predictive analytics systems in a way which they influence good policy choices in turbulent times?* (2) *What are technological, political, and institutional barriers to proactive use of predictive analytics systems?* We address these research questions by adopting a "Model of Strategic Decision-Making Effectiveness" [15, p. 373], because this model provides variables which are relevant to our topic of policy decision-making effectiveness made in turbulent times. However, we modify the model by adding a new variable: information technology (IT) use/predictive analytics system use.

HICSS

A specific research context draws on the 3.11 compound catastrophe that devastated Fukushima prefecture at the north eastern part of Japan. In the immediate aftermath of the March 11 2011 Japan Great East Earthquake and the subsequent tsunamis in excess of 14 meters, Fukushima Daiichi Nuclear Power Plant (herein called "F1" by its owner, Tokyo Electric Power Company, Ltd. – TEPCO) lost both main external power supplies and internal back-up generators, causing reactor core meltdowns which were rated as Level 7 (the worst kind) by The International Atomic Energy Agency (IAEA). In this policy decision-making context, Japan's policy makers showed the varying levels of intensive use of an advanced predictive analytics distributed network system – "System for Prediction of Environmental Emergency Dose Information Network System" (referred to as "SPEEDI").

While our research context is the compound catastrophe, this paper's central focus is not disaster management research. It is centrally focused on the varying use of SPEEDI-generated information and its impacts on policy decision-making effectiveness that influenced the critical mass evacuation policy choices.

The rest of this paper is structured as follows: A review of relevant literatures is presented in Section 2. Our research context is described in Section 3. Section 4 describes our research methodology. Section 5 discusses our key findings. Finally, Section 6 presents our discussion and conclusions.

2. Literature review

2.1. Policy decision-making effectiveness in turbulent times

"A Model of Strategic Decision-Making Effectiveness" explicates private-sector strategic decision process and strategic decision-making effectiveness [15, p. 373]. Despite its original private-sector orientation, the model identifies variables of importance to study strategic decisions. We further hold that the government's policy decisions made in turbulent times are largely *strategic* decisions in that they are designed to influence favorably the key factors such as resource allocation, knowledge sharing, and stakeholder buy-in on which the desired policy outcomes critically depend. Moreover, we modified the original model by adding a new model concept: use of IT, because recent studies show the impacts of IT-enabled organizational agility [36, 48] customer agility [31, 41] in sensing and responding to rapidly changing decision environments in turbulent times.

The original model postulates that strategic decision-making effectiveness (SDME) is a function of presence of *procedural rationality* (PR) and absence of *political behavior* (PB) [15]. The model identifies *environmental favorability* (EF) and *quality of implementation* (QI) as control variables that are outside the main focus of their study but can indirectly influence strategic decision-making effectiveness. Finally, environmental instability (EI) positively moderates the relationship between PR and SDME and the relationship between EF and SDME. Figure 1 shows this Model in a modified graphical presentation. A solid line shows a direct effect, whereas a dotted line shows an indirect effect.

Procedural rationality is defined as the extent to which decision processes involve the collection of relevant information and the analysis of this information to make a right choice which can lead to SDMD. Political behavior is the result of decision makers in organizations having different self-interests and being able to use their political influence on decisions, which can hinder achieving SDME.
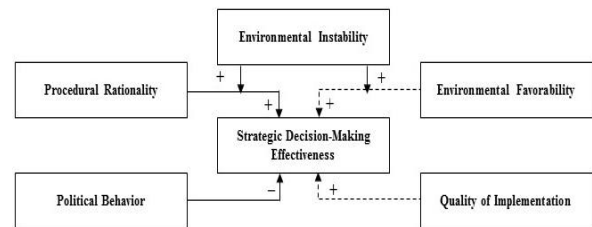
Figure 1. A model of strategic decision-making effectiveness

Environmental instability is defined as a dynamically changing external environment that results from a shift in market demand and the introduction of new disruptive technologies. Because PR basically represents the collective information processing capacity, the Model argues that the relationship between PR and SDME is stronger in turbulent environments. Environmental favorability is defined as "the extent to which environmental conditions subsequent to a decision favor the choice that was made." [15, p. 377]. Finally, the quality of decision implementation underscores the competence with which the proper steps are taken to execute the strategic decision. While our study adopts this model, it must be noted that the model does not consider the role of information technology (IT) use in enhancing SDME.

There are increased scope, complexity, and political aspects of crisis that make strategic and political decision making especially challenging for policy makers [5]. Policy makers have a tendency to

claim they cannot be held responsible for the occurrence of a particular crisis, while at the same time they assume that they are well prepared for any crisis that occurs and take effective measures to protect the public in the event of a crisis in these fast moving environments. Similarly, firms' problem solving strategies in high velocity environments occur with a bounded rationality approach. Firms that survived in these high velocity environments are able to make agile decisions which enhance performance through confidence to act, effective group processes, and accelerated cognitive processing [16].

Traditionally, in crisis management there is an expectation that decisions will be centralized. However, research shows that there is multiple decision-making taking place simultaneously such as informal decentralization, non-decision making, and paralysis [5]. In an examination of the Fukushima crisis in Japan [6] argues that there is persistent myth that crisis management operations are best organized in a command and control mode. However, this goes against the first phase of a crisis where there typically is a lack of information, communication, and coordination and it is impossible to control all first responders. Therefore, under these circumstances effective response is more improvised, flexible, and networked, rather than standardized, planned, and centrally led. The case of Fukushima was a paradigm-shifting crisis that came as a total surprise to the Japanese policy makers and the Japanese government's hyper-centralized approach to crisis management was seriously questioned [6]. Furthermore, empirical research on the 2008 financial crisis, when 17 European Union countries tried to reduce their growing budgetary deficits, showed that increased centralization of decisions leads to more centralization throughout the system [40]. The stronger the pressure from the outside for change leads to greater centralized decisions.

In an analysis of government dimensions of crisis management three important lessons have learned [42]. First, a crisis typically raises questions about the ineffectiveness of government agencies and authorities in preventing the occurrence of the crisis in the first place. Second, the frequency of government action or inaction does not mean that government action is always beneficial since they may do things that could make the crisis worse. Third, crisis and political events are found within the political sphere and this can have a tremendous influence on the decisions that are made during and after a crisis [32].

In regards to policy making the challenges of crisis management deal with several important issues [6]. First, there are political-administrative challenges of preparing government agencies to deal with adverse situations that arise. Second, crisis impacts its citizens and institutions in a fundamental way and citizens' must demonstrate resilience to bounce back after the crisis to establish "normality." Third, crisis requires policy makers to be "deep thinkers" about how to move effectively forward. Crisis typically comes as a surprise to leaders and their agencies and represents the hardest challenges that political leaders have ever encountered. However, despite all of these challenges, policy makers will ultimately be held accountable for their failures.

2.2. Predictive analytics & decision-making effectiveness

Predictive analytics are data-driven software tools that draw on confirmed relationships between variables to predict *future outcomes*. The predictions that predictive analytics produce are often values, indicating the likelihood of a particular behavior or event to occur in the future [23]. Advanced analytics-driven data analyses, which use data, text, and web mining technologies, enable strategic decision makers to have a full "360 degrees" view of their operations and customers [7, p. 155]. Predictive analytics not only generate useful models but also complement explanatory modeling in theory building and theory testing. Despite the importance of predictive analytics, however, the use of predictive analytics is still very new in the information systems (IS) literature [3, 35, 46].

While it is not about *predictive* analytics use, a survey research draws on the information processing view and contingency theory to examine the effect of (descriptive) business analytics use on decision-making effectiveness at the organizational level [10]. Structural equation modeling analysis found that business analytics use positively influences information processing capability in data-driven decision environments. This in turn has a positive effect on improving decision-making effectiveness.

Prior research showed that organizations have largely failed to use other types of (non-predictive) business analytics – so-called business intelligence (BI) systems effectively – to exploit the huge volumes of data they captured in their enterprise resource planning (ERP) systems. BI systems use analytics and enterprise system databases. As a result, BI systems failed to support managerial decision making at both the strategic and operational levels, and hence failing to create business value through BI investments [17, 18]. This empirical study found evidence for the importance of BI systems assimilation and the need for shared domain

knowledge at the strategic and operational levels as the drivers of BI business value. Moreover, the study suggests the critical importance of organizational absorptive capacity, which is the competence to collect, absorb, and strategically leverage new external information, in developing appropriate technology infrastructure and assimilating BI systems for managerial decision-making effectiveness. Finally, the study found that operational managers' absorptive capacity matters to leveraging BI systems, although top management plays a significant role in effective deployment of BI systems but their influence is indirect. This suggests the key to leveraging BI systems is BI systems assimilation and use from the bottom up as opposed to the top down [17].

3. Research context

3.1. Nuclear reactor meltdowns

A magnitude 9.0 earthquake struck east of Sendai, Japan, northeast of Tokyo, at 14:46 on March 23, 2011. The strongest earthquake recorded in Japan triggered enormous tsunamis of over 14 meters (46 feet). With the epicenter of the earthquake being so close to coastal villages and towns, 15,076 people were drowned, 10,354 still missing, and more than 460,000 citizens were evacuated as of July 2011, although Japan Meteorological Agency's national tsunami warning system issued severe tsunami early warnings at 14:49 [45] within 3 minutes of the M9.0 earthquake. Many who were drown were trapped in their cars which could not move due to the traffic jam when the tsunamis arrived. They ignored police's repeated warnings not to use cars for evacuation for this reason.

As the tsunamis flooded inland areas several kilometers from shore in Fukushima prefecture of the Tōhoku region around 15:30, F1 built on a high ground 10 meter above the sea level was seriously impacted. The tsunamis destroyed the two main power supplies as well as the backup power generators in the basement at 15:42, having rendered all the mission-critical systems inoperable at Reactors 1-3 for a sustained period of time, including the nuclear reactor cooling systems, containment systems, the sensor-based environmental radiation monitoring systems, reactor control rooms' information systems, electrical equipment, transformers and safety equipment. Furthermore, an off-site nuclear emergency command and control center for F1 was also powerless and could not perform its emergency command, control, coordination, and communication functions.

The central government issued the F1 nuclear emergency declaration at 19:03 on March 11. Despite the frantic efforts to regain control over the rapidly evolving nuclear emergency, nuclear reactor core meltdowns occurred at the F1 site, with a powerful explosion at the No. 1 reactor at 15:36 on March 12, another explosion at the No. 3 reactor at 11:01 on March 14, and a third explosion at the No. 2 reactor at 6:14 on March 15. In the immediate aftermath of the No. 2 reactor explosion, hourly radioactive material emissions reached 8,217 microsieverts near the F1's main gate at 8:31 on March 15 [45] and over 1,015 microsieverts soon afterwards [28] with the detection of dangerous levels of radioactive material in milk and other local food products on March 19 and in drinking water of Fukushima's five local government areas on March 22 [45]. Citizens living in the region were at the edge of the most serious case of radioactive contamination since the former Soviet Union's Chernobyl disaster in 1986.
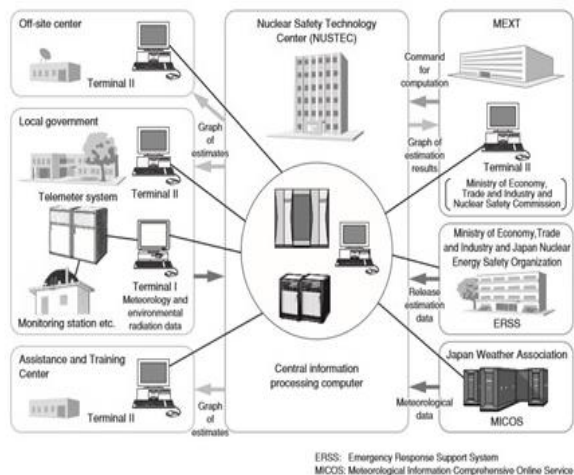
Using the International Nuclear and Radiological Event Scale (INES) used by the International Atomic Energy Agency (IAEA), Japan Atomic Energy Agency (JAEA) rated each reactor accident separately. FI has six reactors and four of which were operational at the time of the earthquake. Of the four, the three reactors with the explosions were rated at the Level 5, while one was rated at the Level 3. JAEA rated the overall F1 nuclear accident as a Level 7 on the INES based on the monitoring of high radioactive releases over days 4 to 6, with eventually a total of some 940 PBq (I-131 eq) [28].

3.2. SPEEDI predictive analytics system

The System for Prediction of Environment Emergency Dose Information (SPEEDI) is Japan's predictive analytics network system specifically developed *to predict and visualize* the dispersion and density of radioactive material emissions on geo-spatial maps and *to support the national evacuation policy decision-making effectiveness* [19]. The predictive analytics network system was built by Fujitsu, Japan in 1986 at a cost of $US 140 million (11 billion yen) for the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The 2016 fiscal year budget for operating SPEEDI is Yen 710 million ($US 6.28 million) [54]. The motivation for the initial development of SPEEDI was US Three Mile Island nuclear accident in 1979. In 1980 JAEA undertook the conceptual design with an initial system being completed in 1984. With continuous investments in hardware updates and advanced modelling capability enhancements, the SPEEDI network system since 2005 can

automatically provide governments at all levels with *highly advanced predictive analytics capabilities* in providing real-time forecasts of extreme weather events and predictions of radiation flume directions shown on geo-spatial maps in response to nuclear accidents and radiological emergencies.

Based on [37] Figure 2 shows a process view of the SPEEDI network system architecture. SPEEDI receives two other inputs: (1) meteorological data from Japan Weather Association MICOS and (2) radioactive material release estimate data from ERSS. ERSS in turn receives streaming big data automatically sent from a national distributed network of sensors for environmental radiation monitoring located at Japan's 53 operational nuclear power plants. SPEEDI operation and usage are governed by Japan's Nuclear Safety Commission (NUSTEC) which was established within the Cabinet of Japan as an independent lead agency in nuclear safety administration [62]. Importantly, once the nuclear emergency declaration is issued by the Prime Minister of Japan, SPEEDI use is *legally mandated* through the Nuclear Safety Directive [39].

ERSS: Emergency Response Support System
MICOS: Meteorological Information Comprehensive Online Service

Figure 2. A process view of SPEEDI

SPEEDI predictive modeling and analytics outputs – dispersion and density of radioactive material emissions on geo-spatial maps – are *automatically* sent to the SPEEDI Network System terminals distributed across: (1) central, state and local governments, (2) off-site nuclear emergency control centers, (3) Cabinet's nuclear emergency response council, (4) MEXT, and (5) Ministry of Economy, Trade and Industry's (MITI) Japan Nuclear Energy Safety Organization based on the 2012 NUSTEC's Environmental Radiation Monitoring Directive (p. 171).

4. Research methodology

In order to address the two research questions, we have adopted a case study research methodology which comprises field observations, ethnographic document analysis and semi-structured case interviews.

An ethnographic approach to document analysis argues that "an ethnographic perspective can help delineate patterns of human action when document analysis is conceptualized as fieldwork" [2, p. 65]. Similarly, documents are viewed as a critical data source in qualitative research and in the context of conducting rigorous document analysis procedure, including technical document [34], researchers can have virtual field research experiences [8].

This research specifically examined three different documents: (1) Government Report (a total of 592 pages in Japanese) compiled by National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (so-called Jikochou) chaired by Professor Kiyoshi Kurokawa, a policy analysis expert with nine commission members with diverse backgrounds, (2) Private-Sector Report (a total of 403 pages with 8 pages of appendix) compiled by Fukushima Nuclear Accident Independent Inspection Commission (so-called Rebuilding Japan Initiative) and (3) book (a total of 238 pages in Japanese) entitled *Nuclear Crisis: Testimony from Prime Minister of Japan and His Cabinet* written by Tetsuro Fukuyama, Deputy Chief Cabinet Secretary and a politician of the Democratic Party of Japan (DPJ) who was a key policy maker during the reactor meltdowns. During the five days of the intensive nuclear disaster response, Fukuyama recorded facts and observations on four volumes of A4 college notebooks.

Semi-structured case interviews were done with site visits in Fukushima, Miyagi and Iwate – the three Prefectures worst hit by the Great East Japan Earthquake and tsunamis – were made in January 2012 prior to conducting case interviews with three policy experts at Fukushima Prefectural (or state) government responsible for disaster response and evacuation policies and evacuation policy implementation. Each semi-structured case interview was conducted in Japanese and lasted approximately 90 minutes. An additional interview was conducted for an hour with a middle-level manager who was familiar with SPEEDI use. In 2012 we conducted intensive semi-structured interviews with a local commercial radio station, Fukushima Radio: board members and radio announcers who had first-hand experiences in running emergency broadcasting

services during the compound disasters, blackouts, and the absolute lack of official disaster information.

5. Results

5.1. Varying proactive use of SPEEDI

Despite the government investments in ERSS and SPEEDI to support citizen protection, mass evacuation policy development and policy implementation in case of severe nuclear accident, ERSS could not provide SPEEDI with timely and accurate radioactive material release streaming big data due to the problems with environmental monitoring sensors located at the F1 site during the sustained blackouts. As a result of this data quality issue, the predictions of SPEEDI on radioactive material dose density and dispersion directions were viewed by the central government as "unreliable" and its information use to formulate evacuation policies as "too risky" for citizen safety [39, p. 383]. As early as on March 15, 2011 – four days after the 3.11 catastrophe, Yomiuri Newspaper reported "problems with SPEEDI" [25, p. 35] without sufficient technical explanations of the root cause of ERSS whose outputs fuel SPEEDI. Some nuclear scientists with the knowledge of SPEEDI predictive analytics capabilities started to tweet on Twitter to urge the government to use SPEEDI [25]. Even though the use of SPEEDI was legally mandatory in Japan, after the Prime Minister Kan's national nuclear emergency declaration [29], the Kan administration's nuclear crisis response headquarters did not know the existence of SPEEDI until the government's top spokesman, Yukio Edano, was asked by journalists why SPEEDI was not deployed to help government more effectively respond to the enfolding nuclear accident during one of his frequent TV interviews [19, 25].

Against this background, however, at 16:00 on March 11 (an hour and 14 minutes after the M9.0 earthquake devastated Fukushima), the Nuclear Safety Technology Center responsible for the operation of SPEEDI provided MEXT (the central government ministry that outsourced the development of SPEEDI) with the first SPEEDI predictive analytics outputs in the immediate aftermath of the F1 blackout. At this time SPEEDI was operational in the *normal* operation mode. At 16:40 the operation of SPEEDI shifted to the *crisis* operation mode [25]. Various mass media reported that over 1,000 (even over 5,000) pages of SPEEDI data/outputs were generated by NUSTEC during the first five critical days of the F1 reactor meltdowns.

Using the *geo-spatial maps* of radioactive material density and dispersion directions (SPEEDI predictions), MEXT could send radiation monitoring cars to collect *actual real-time* environmental radiation data from the affected local areas. However, according to Akira Tsubosaka, a senior MEXT official responsible for the SPEEDI operation, the Japanese central government did not publish the SPEEDI data proactively and openly until March 23, 2011 when it was pressured to do so [19, 27, 39, 52].

Our case interview of the Fukushima Prefectural (or state-level) government's manager who was knowledgeable of SPEEDI predictive analytics capabilities acknowledged that they had received the SPEEDI predictions automatically sent from MEXT, which were timely used for their citizen evacuation decisions. Other two interviewees responsible for evacuation policy implementation observed that while the local governments might have also received the SPEEDI predictions, many of them lost their key staff and suffered substantial damage to their IT infrastructure and information processing capacity and might not be able to use SPEEDI predictions effectively and timely.

5.2. Mass evacuation policy conundrum

The Kan administration's nuclear emergency response headquarters reviewed the enfolding nuclear crisis, under the conditions of (1) a very sporadic limited information and knowledge sharing on the part of TEPCO regarding the F1 nuclear crisis response operations, and (2) the absence of local disaster communications from the Fukushima Prefecture governor and the local government leaders [19]. The Kan administration's nuclear crisis response headquarters were particularly frustrated with the lack of transparency and the inability of Mr. Takekuro, TEPCO Fellow, who was purposefully co-located at the headquarters to facilitate open information sharing and knowledge transfer between the central government and TEPCO [19], which raised the question of TEPCO's institutional trustworthiness [33]. Against these turbulent and uncertain decision environments, the central government, still without using SPEEDI, discussed that a best evacuation policy option might be to use the existing standard evacuation policy with very limited scale nuclear emergency mass evacuation operations, which could minimize the local citizens' unnecessary radiation exposure. However, the headquarters' policy decision makers eventually decided against the existing standard evacuation policy of 3 kilometer radius of the F1 site. Instead they decided to escalate the scale to a temporary

exclusion zone of 10 kilometer (6.2 miles) at 3:59 on March 12 [19].

Without the use of SPEEDI, the central government was in the dark as to the predicted directions of radio-active material flows. Logistically, local governments needed to provide the public with ground transportation, the evacuation centers, food, water, heaters and blankets in the cold month of March. Many roads were still totally or partially impassable, causing the absolute shortage of gasoline for cars [19].

Meanwhile, at the time of the central government's initial evacuation policy announcement to the state and the local governments, TEPCO was attempting to open four emergency bents manually to avoid hydrogen explosions. Despite the highly risky "heroic' efforts made by TEPCO engineers who determined to stay at the site to regain operational control over the damaged nuclear reactors, the first sighting of white smoke/steam was reported at the No. 1 reactor. This incident accelerated the speed of mass evacuations at 10:17 on March 12. Later at 15:36 first hydrogen explosions occurred at the No. 1 reactor before the initial mass evacuation was completed [45].

The second hydrogen explosions at the No. 3 reactor occurred at 11:01 on March 14. Another hydrogen explosions at the No. 2 reactor followed at 6:14 on March 15. In the immediate aftermath of the explosions, TEPCO recorded an extremely dangerous level of 817 microsieverts radioactive material near the main gate. With the enfolding and escalating nuclear disasters, the central government revised the earlier 10 kilometer mass evacuation policy and issued an escalated 20 kilometer (12 miles) radius around the F1 site and a 30 kilometers (19 miles) radius voluntary evacuation zone from the F1 site. This revised mass evacuation policy was made again without any SPEEDI predictions and meaningful insights into the density and dispersion of radioactive material subject to the prevailing weather and geographical conditions for which SPEEDI was designed, developed and was actually operated at the time by MEXT [39]. Perhaps due to their own lack of knowledge about SPEEDI capability as well as the lack of openness and transparency on the part of TEPCO senior executives, the nuclear emergency response headquarters continued to revise the critical mass evacuation policies in the dark and blindfolded in the initial time-critical turbulent times.

Later when the Kan administration learned about the SPEEDI predictive analytics distributed network system, the Prime Minister with a Master's degree in engineering from Japan's top engineering university gathered a small group of trusted nuclear scientists who had expert knowledge of SPEEDI predictive modelling capabilities. The group through their effective use of SPEEDI could rapidly answer the technical questions the policy makers raised. Importantly, for example, one scientist managed to bypass the data quality problem related to ERSS and produced usable and valuable predictive modelling and analytics results through his intensive use of SPEEDI for the policy makers [20].

5.3. Damage to perceived political efficacy

The various Fukushima Nuclear Accident inquiry reports that were tabled severely criticized the Kan administration's ineffective and slow responses to the escalating nuclear crisis, demanding his resignation. In response DPJ Prime Minister Naoto Kan resigned in August 2011 [50]. The opposition party, LDP, won the parliamentary elections in December 2012 and LDP Prime Minister Yoshihiko Noda was inaugurated. More recently, Prime Minister Shinzo Abe, the President of the Liberal Democratic Party (LDP) was inaugurated as the third Abe administration in December 2014.

Both Prime Minister Naoto Kan and his Deputy Chief Cabinet Secretary Fukuyama experienced the terror of the reactor meltdowns with its clear and imminent danger which could end the nation. They both reached the same conclusion: Japan must stop its heavy reliance on 53 nuclear reactors for power generation [29].

On the one hand, based on post-earthquake assessments of the effectiveness of the existing nuclear regulatory authority, a new nuclear regulatory agency and new standards for nuclear power plants were created [22, 53]. On the other hand, on March 16, 2016, the commissioners of Japan's Nuclear Regulation Authority (NRA) rejected a request made, in December 2015, by 12 Japanese Prefectural Governors that NRA need to continue to operating SPEEDI to help determine best evacuation policy options in the event of a severe accident [54]. Finally, as for TEPCO, in February 2016, three former senior executives responsible for the governance of the F1 operation, were criminally charged with professional negligence resulting in deaths and injury for their role in the 2011 "man-made" nuclear accident [14].

5.4. Barriers to proactive use of SPEEDI

On the surface, the general lack of technological knowledge and understanding of SPEEDI system and mistrust in data quality [24] were the key barriers to proactive use of SPEEDI by the central government in general and the key policy decision makers of the

nuclear emergency response headquarters in particular. Strategically, it is difficult to understand the complete failure to use SPEEDI by the central government, given the Directive, the existing legal framework, mandates proactive use of SPEEDI once the declaration of the national nuclear emergency is made by the Prime Minister of Japan.

At deeper levels, however, there are underlying political and institutional factors that contributed to the general lack of technical knowledge and understanding of SPEEDI predictive analytical capabilities among Japan's policy decision makers and policy implementers. Politically, Japan's central governments rapidly and frequently changed, with 18 different prime ministers and 3 different political parties (LDP 12 times, JNP once, JRP once, JSP once and DPJ three times) since 1987 to the present which roughly covers the period which SPEEDI was conceptually designed, developed and operated. In general, Japan's central government pushed technological innovations for economic development and global competitiveness. But as the policy decision makers so rapidly changed, the general knowledge of SPEEDI might not be transferred from one administration to another. Institutionally, there has been serious problems of government silos and technology fear [26] and inter-agency distrust [4; 9], making inter-agency communication, collaboration and knowledge sharing difficult.

The Nuclear Safety Technology Center responsible for the operation of SPEEDI was located within MEXT to safeguard citizens and society from nuclear accidents, whereas the now defunct nuclear regulatory authority at the time of the Fukushima nuclear accident was located within the Ministry of Economy, Trade and Industry which has been the key driver for nuclear energy policy and nuclear industry development.

6. Discussion and Conclusion

As we discussed our key findings in the previous section, MEXT used the SPEEDI predictive analytics distributed network system to produce and distribute the predictions, despite the ERSS data quality problem without much delay in the aftermath of the 3.11 compound catastrophe that devastated Fukushima, Miyagi and Iwate prefectures. Moreover, MEXT used the predictions to dispatch monitoring cars to the high-risk local areas, using the SPEEDI-produced geo-spatial maps, to collect radioactive material release data in real time. These data replaced the streaming big data that could not be provided by ERSS, and hence improving the values of SPEEDI predictive analytics over time. In addition to MEXT's

proactive use of SPEEDI at the central government level, the geospatial maps, outputs of SPEEDI predictive analytics, were automatically sent to the Fukushima Prefectural government which used the predictions timely for enhancing their mass evacuation policy decision making effectiveness. The state government policy makers could urge some of the local governments to launce immediate evacuation operations, without waiting for the central government's much delayed initial evacuation policy announcement. In stark contrast, the central government policy decision makers failed to proactively use SPEEDI.

Our results indicate *how* predictive analytics systems are used – either proactively and intensively or reactively or latently – seemed to facilitate (or inhibit) the extent of strategic agility and operational flexibility with which strategically and politically critical policy decisions are made. Using the adapted model of strategic decision-making effectiveness [15], we interpret our key findings and argue that the relative absence of procedural rationality (PR) combined with the clear presence of political behavior (PB) may explain the failed proactive use of SPEEDI by the key policy decision makers of the nuclear emergency response headquarters at the central government. The deeper underlying inhibitive barriers we discussed in the previous section may have contributed to the relative absence of PR and the clear presence of PB. In contrast, the proactive use of SPEEDI by MEXT and the Fukushima Prefectural government can show some evidence of the enabling role of SPEEDI in increasing PR.

According to Mr. Tetsuro Fukuyama, the then DPJ Deputy Chief Cabinet Secretary, Kan's trusted policy chief, the Cabinet policy makers struggled to obtain accurate and timely information from TEPCO on the extent of the damage to the F1 site [19]. Both Fukuyama in his book and Prime Minister in his book [29] expressed their high-level frustration with the lack of competence of the TEPCO Fellow and other nuclear technology experts in informing the policy makers. This may be interpreted as the presence of PB or the problem of extant knowledge divide between TEPCO and the Japanese policy makers, hence hindering cognitive absorptive capacity [1], knowledge sharing [49] and trust in data quality [47].

In answering these questions, this study contributes to new research on predictive analytics use in government towards policy decision-making effectiveness by increasing PR and controlling PB, with the need for more input and analytical insights from (1) the proactive use of predictive analytics, (2) engagement of external experts through the shared use of predictive analytics tools, and (3) through the

distributed use of said tools, engagement of local government decision makers who are tasked to implement the central government's evacuation policy. We hold that such an open policy making will create greater public values for citizens and society, while mitigating political and institutional barriers in turbulent times. However, we have research limitations that result from not having access to the policy decision makers through case interviews. Our future research directions include the application of the modified model of strategic decision-making effectiveness, with the added concept of IT use, to interview local-level policy decision makers.

8. References

[1] Agarwal, R., and Karahanna, E. "Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage," *MIS Quarterly*, 24(4), 2000, pp. 665-694.

[2] Altheide, D. L. "Reflections: Ethnographic content analysis," *Qualitative Sociology*, 10(1), 1987, pp. 65-77.

[3] Bardhan, I., Oh, J.-H., Zheng, Z., and Kirksey, K. "Predictive analytics for readmission of patients with congestive heart failure," *Information Systems Research* 26(1), 2015, pp. 19-39.

[4] Bigley, G. A., and Pearce, J. L. "Straining for shared meaning in organization science: Problems of trust and distrust," *Academy of Management Review*, 23(3), 1998, pp. 405-421.

[5] Boin, A., and 't Hart, P. "Public leadership in times of crisis: Mission impossible?" *Public Administration Review,* 63(5), 2003, pp. 544-553.

[6] Boin, A. "The new world of crises and crisis management: Implications for policymaking and research,"

Review of Policy Research, 26(4), 2009, pp. 367-377.

[7] Bose, R. "Advanced analytics: Opportunities and challenges," *Industrial Management and Data Systems*, 109(2), 2009, pp. 155-172.

[8] Bowen, G.A., 2009. "Document analysis as a qualitative research method," *Qualitative Research Journal*, 9(2), 2009, pp. 27-40.

[9] Brown, S.A., Massey, A.P., and Ward, K.W. "Handle mergers and acquisitions with care: The fragility of trust between the IT-service provider and end-users," *European Journal of Information Systems*, 25(2), 2016, pp. 170-186.

[10] Cao, G., Duan, Y., and Li, G. 2015. "Linking business analytics to decision making effectiveness: A path model analysis," *IEEE Transactions on Engineering Management*, 62(3), 2015, pp. 384-395.

[11] Celik, S., and Corbacloglu, S. "Role of information in collective action in dynamic disaster environments," *Disaster*, 3(1), 2010, pp. 137-154.

[12] Chatfield, A. T., and Reddick, C. G. "Understanding risk communication gaps through e-government website and Twitter hashtag content analyses: The case of Twitter hashtag content analyses: The case of Indonesia's Mt. Sinabung eruption," *Journal of Homeland Security and Emergency Management*, 12(2), 2015, pp. 351-386.

[13] Chatfield, A.T., Reddick, C.G., and Al-Zubaidi, W. "Capability challenges in transforming government through open and big data: Tales of two cities," *Proceedings of the* Thirty Sixth *International Conference on Information Systems (ICIS)*, Fort Worth, Texas, December 13 –17, 2015, 1-20.

[14] Daily Mail Australia. 2016. "Former TEPCO bosses indicted over Fukushima disaster," February 29, 2016, http://www.dailymail.co.uk/wires/afp/article-3468902/Ex-TEPCO-execs-indicted-Fukushima-accident.html.

[15] Dean, J. W., & Sharfman, M. P. "Does decision process matter? A study of strategic decision-making effectiveness," *Academy of Management Journal, 39*(2), 1996, pp. 368-396.

[16] Eisenhardt, K. M. "Making fast strategic decisions in high-velocity environments," *The Academy of Management Journal, 32(*3), 1989, pp. 543-576.

[17] Elbashir, M. Z., Coollier, P. A., and Sutton, S. G. "The role of organizational absorptive capacity in strategic use of business intelligence to support integrated management control systems," *Accounting Review*, 86(1), 2011, pp. 155-184.

[18] Elbashir, M. Z., Coollier, P. A., Sutton, S. G., Davern, M. J., and Leech, S. A. "Enhancing the business value of business intelligence: The role of shared knowledge and assimilation," *Journal of Information Systems*, 27(2), 2013, pp. 87-105.

[19] Fukuyama, T. *Genpatsu Kiki Kantei kara no Shougen* (*Nuclear Crisis A Testimony from Prime Minister of Japan and His Cabinet*), Tokyo: Chikuma Shobou.

[20] Funabashi, Y. *Countdown to Meltdown* Volume II, Tokyo: Bungeishunju, 2012.

[21] Gandomi, A., and Haider, M. "Beyond the hype: Big data concepts, methods, and analytics**,"** *International Journal of Information Management*, 35(2), 2015, pp. 137-144.

[22] GAO. *Nuclear Safety Countries' Regulatory Bodies*

Have Made Changes in Response to the Fukushima Daiichi Accident, GAO-14-109, March 2014, Washington D.C. United States Government Accountability Office.

[23] Hair Jr., J. F. "Knowledge creation in marketing: The role of predictive analytics," *European Business Review*, 19(4), 2007, pp. 303-315.

[24] Hazen, B. T., Boone, C. A., Ezell, J. D., and Jones-Farmer, L. A. "Data quality for data science, predictive analytics, and big data in supply chain management: An introduction to the problem and suggestions for research and applications," *International Journal of Production Economics* (154: August), 2014, pp. 72-80.

[25] Hizumi, K., and Kino, R. *Fukushima Nuclear Accident. What Did Government and TEPCO Hide? Journalist Interviews*, Iwanami Books, Tokyo, 2012.

[26] Hsiao, R-L. "Technology fears: Distrust and cultural persistence in electronic marketplace adoption," *Journal of*

Strategic Information Systems, 12(3), 2003, pp. 169-199.

[27] Independent Investigation Commission. *The Fukushima Nuclear Accident Investigation Report*, February 6, 2012, Rebuild Japan Initiative NPO.

[28] Japanese Ministry of Environment. *H24 Environment White Paper*, Tokyo: Ministry of Environment, 2012.

[29] Kan, N. What I reflect on Fukushima Nuclear Accident as the Prime Minister of Japan, Gentosha Publishing, Tokyo, 2012.

[30] Klatt T., Schlaefke, M., and Moeller, K. "Integrating business analytics into strategic planning for better performance," *Journal of Business Strategy*, 32(6), 2011, pp. 30-39.

[31] Koch, H. "Developing dynamic capabilities in electronic marketplaces: A cross-case study," *Journal of Strategic Information Systems*, 19 (1), 2010, pp. 28-38.

[32] Kouzmin, A. "Crisis management in crisis?" *Administrative Theory & Praxis, 30*(2), 2008, pp. 155-183.

[33] La Porte, T. R., and Metlay, D. S. "Hazards and institutional trustworthiness: Facing a deficit of trust," *Public Administration Review* (56:4), 1996, pp. 341-347.

[34] Lee, S., Mortara, L., Kerr, C., Phaal, R., and Probert, D. "Analysis of document-mining techniques and tools for technology intelligence: Discovering knowledge from technical documents," *International Journal of Technology Management*, 60(1-2), 2012, pp. 130-156.

[35] Lim, E.-P., Chen, H., and Chen, G. "Business intelligence and analytics: Research directions," *ACM Transactions on Management Information Systems*, 3(4), 2013, Article number 17.

[36] Mao, Y., and Quan, J. "IT enabled organisational agility: Evidence from Chinese firms," *Journal of Organizational and End User Computing*, 27 (4), 2015, pp. 1-24.

[37] Misawa, M., and Nagamori, F. "System for prediction of environmental emergency dose information network system," *Fujitsu Science Technology Journal*, 44(4), 2008, pp. 377-388.

[38] Nakamura, A., and Kikuchi, M. "What we know, and what have not yet learned: Triple disasters and the Fukushima nuclear fiasco in Japan," *Public Administration Review*, 71(6), 2011, pp. 893-899.

[39] National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission. *NAIIC Report*, September 30, 2012.

[40] Raudla, R., Douglas, J. W., Randma-Liiv, T., and Savi, R. "The impact of fiscal crisis on decision-making processes in European governments: Dynamics of a centralization cascade," *Public Administration Review, 75*(6), 2015, 842-852.

[41] Roberts, N., and Grover, V. "Leveraging information technology infrastructure to facilitate a firm's customer agility and competitive activity: An empirical investigation," *Journal of Management Information Systems*, 28 (4), 2012, pp. 231-270.

[42] Rosenthal, U., and Kouzmin, A. "Crises and crisis management: Toward comprehensive government decision making," *Journal of Public Administration Research and Theory: J-PART, 7*(2), 1997, pp. 277-304.

[43] Sabherwal, R., and Becerra-Fernandez, I. "Integrating specific knowledge: Insights from the Kennedy Space Center," *IEEE Transactions on Engineering Management*, 52(3), 2005, pp. 301-315.

[44] Schläfke, M., Silvi, R., and Moller, K. "A framework for business analytics in performance management," *International Journal of Productivity and Performance Management*, 62(1), 2013, pp. 110-122.

[45] Seibido Mook. Chizu de Yomu Higashi Nihondaishinsai (Understanding Great East Japan Disasters through maps), Seibido Shuppan, Tokyo, July 2011.

[46] Shmueli, G., and Koppius, O.R. "Predictive analytics in information systems research," *MIS Quarterly*, 35(3), 2011, pp. 553-572.

[47] Storey, V. C., Dewan, R. M., and Freimer, M. "Data quality: Setting organizational policies," *Decision Support Systems*, 54(1), 2012, pp. 434-442.

[48] Tallon, P.P., and Pinsonneault, A. "Competing perspectives on the link between strategic information technology alignment and organizational agility: Insights from a mediation model," *MIS Quarterly: Management Information Systems*, 35 (2), 2011, pp. 463-486.

[49] Taylor, W. A., and Wright, G. H. "Organizational readiness for successful knowledge sharing: Challenges for public sector managers," *Information Resources Management Journal*, 17(2), 2004, pp. 22-37.

[50] Tabuchi, H. "Japan's PM called to resign over crisis," *Sydney Morning Herald*, April 16-17, 2011.

[51] Turkman, P., McCormack, K., Oliveira, M.V., and Ladeira, M.B. "The Impact of Business Analytics on Supply Chain Performance," *Decision Support Systems*, 49(3), 2010, pp. 318-327.

[52] Tsubosaka, S., and Sasahara, T. "On the Fukushima Nuclear Crisis SPEEDI Maps," *Backyard World*, July 19, 2011, https://backyardworld.wordpress.com/maps/speedi/.

[53] Umeda, K. *Fukushima Nuclear Accident*, Iwanami Books, Tokyo, 2013.

[54] Ushio, S. "NRA rejects Japan Governors' request to use dose rate prediction system," *Platts Inside NRC*, 38(6), March 21, 2016.

[55] von Lubitz, D.K., Beakley, J.E., and Patricelli, F. "All hazards approach to disaster management: The role of information and knowledge management, Boyd's OODA loop, and network-centricity," *Disaster*, 32(4), 2008, pp. 561-585.

[56] Waller, M.A., and Fawcett, S.E. "Data science, predictive analytics, and big data: A revolution that will transform supply chain design and management," *Journal of Business Logistics*, 34(2), 2013, pp. 77-84.