

Achieving Electric Restoration Logistical Efficiencies During Critical Infrastructure Crisis Response: A Knowledge Management Analysis

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Abstract

After the 2007 Southern California wildfire events, event-assessment of the efficacy of spreadsheets and paper forms raised the question of whether alternative tools could have achieved greater efficiencies in the logistical support of command centers, the sites from which the local utility's electric restoration personnel were deployed. The purpose of this study is to examine what approach would have enabled personnel working on the logistics of the command center effort to have easier-to-use, faster-to-access, command center data stored in, and provided via, a catastrophe resilient platform other than the traditional company computer network. Additionally, the capability to store basic command center requirements from previous emergency responses, to save time during the next emergency, was examined.

Introduction

Gas and electric services in the County of San Diego are provided by San Diego Gas & Electric Company (SDG&E), an investor-owned public utility. Many useful issues can be analyzed from the wildfires that damaged SDG&E's electric system in 2003 and 2007 and certain activities that supported efficient service restoration can be examined and used for comparative analysis for a terrorist attack scenario, earthquakes, wildfires, or any other event that might impact service delivery.

This paper analyzes the logistics support provided during the wild fires to determine what could be improved. This is an important topic as there is little research literature addressing crisis response logistics. Whybark, et al. (2010) discuss disaster relief supply chains but only propose a research agenda. We agree there needs to be research in this area and start with this case study. Logistics/supply chains ensure that responders are able to sustain disaster relief. Their importance is illustrated by the response to the 2009 Haiti earthquake where ships and supplies stood empty or unused off the coast because of an inability to deliver supplies and evacuate injured. Keeping responders in the field is critical for long term disaster relief. Providing relief is critical for affected persons and societies to recover. This paper hopes to start this important research area by exploring alternatives to the spreadsheet approach used in the 2007 wild fires.

Finally, the research question for this paper was what alternatives could be used in lieu of paper forms and spreadsheets to achieve more accurate, timely logistics data and solutions?

Methodology

This paper is a case study using action research to assess whether future activities by the command center support teams can be influenced to convert from paper forms and spreadsheets to something more real-time, as a new solution for crisis response.

The working definition of action research (Zuber-Skerrit and Fletcher, 2007, p. 413) incorporated situations where people reflect and improve (or develop) their own work and their own situations by tightly interlinking their reflection and action; and also making their experience public not only to other participants but also to other persons interested in and concerned about the work and the situation, i.e. their public theories and practices of the work and the situation, and in which the situation is increasingly: data-gathering by participants themselves (or with the help of others) in relation to their own questions; participation (in problem-posing and in answering questions) in decision-making, self-reflection, self-evaluation and self-management by autonomous and responsible persons and groups. This study is action research as the lead author is a team lead of the SDG&E supply chain systems team tasked with assessing logistics performance.

Reflection for this study was done using knowledge management, KM as the reflective lens. Jennex (2005) summarized KM definitions to conclude that KM is about capturing knowledge created in an organization and making it available to those who need it to make decisions and improve organizational performance. Jennex (2007) discussed the role of KM in crisis response and included the role of post event evaluation of lessons learned as a way of capturing knowledge generated during an event and ensuring that knowledge is shared and incorporated into crisis response activities. This implies that KM is a good reflective lens for crisis response research.

The ability to apply KM to the 2007 command center logistical effort and how it can benefit future emergency responders corresponds to KM in support of crisis response as expanded upon by Jennex and Raman (2009). The underlying KM principle upon which this study is constructed are that experience gained from one emergency can be applied as knowledge when shared with others to improve performance during a subsequent emergency. Additionally, improved performance will help an organization meet its goals or mandated objectives acceptably.

Comparing how the basic computer tools used in the 2007 command center set-ups performed against how an alternative process would perform should demonstrate the need to move towards tools that are multi-user, require no consolidation of data, and which can be used with little to no training in the fast-paced environment of an emergency.

Improving an existing business process draws justification from the theory of action research as discussed in the Technology Acceptance Model (TAM) of perceived usefulness (Venkatesh, et al.,

2003). TAM addresses the realm of computer technology and validation of the usefulness of employees' outputs. Davis (1989) verifies the usefulness of the employees' outputs based on their belief of how they performed in that activity. Additionally, Bandura (1982) reiterated the general concept with his self-efficacy model of people's response and reaction being based on their perception of their competency in face of new technologies resulting from the computer and internet evolution. Bandura (1982, p. 122) stated, "A capability is only as good as its execution." Based on this, converting the paper forms and spreadsheets used for the command center logistical effort in 2007 to an alternative tool might be indicated. The action research of this paper is using lessons learned to convert the information tracked in the spreadsheets to a more technological format for easier and faster access in emergency response. This serves as the impetus for improving the existing emergency response process via a technology tool (Bandura, 1982; Davis, 1989; Venkatesh, et al., 2003).

The data used in this paper is from the 2007 Firestorm responses of San Diego Gas & Electric's command center support. Their spreadsheets, emails, phone calls, including the personal observations of the lead author, who participated in the effort, provided the data for this study. The action research format is appropriate for this paper because the research process involved manipulating outputs containing the command center logistical details and their role in the activities in the organization's response to emergency situations. The data that were analyzed related solely to the support of the command center camps and what it took to sustain their mission as bases from which to deploy the electric restoration personnel during the power outages. The details surrounding the ordering, receiving, inventorying, handling, staging, and deployment of construction materials, such as poles and wires, were not the purview of BSLs' work in support of the command centers. Material handling was the responsibility of the Logistics and Warehousing groups.

The spreadsheet listed 25 categories of information that included the following column headings: Region, Need for Site: Yes/Pending, Site Name, Command Center/Staging Area, Site Coordinator & Phone #, Thomas Brothers page, Address, Start Date, Estimated End Date, Total # of People, Food Counts, #B, #L, #D, water buffalo Y/N or 5 gal H2o, # of Porta Potties, Trash bin type: trash/cable/metal/treated wood/recyclables, # of hand-wash stands, Portable Office Trailer, Copier, Lights, Generator(s), Parking Space Reqmnts (Requirements), Material Laydown Space Reqmnts (Requirements), Security, # of

Vehicles, Phone /Data/Radio/Printer, BMP Materials, Notes/Comments.

The data that were examined were three versions of the spreadsheet, Firestorm 2007 - Command Centers and Staging Areas, during the time frame of October 24, 2007 through November 10, 2007, to demonstrate the progression of the command centers' expansion and contraction over time. The spreadsheet also displayed the types of items being tracked at a consolidated level.

Wild Fire Logistics

During the week of October 21, 2007, wind-driven wildfires raged across San Diego County burning more than 360,000 acres and destroying at least 1,700 homes. As soon as the fires had moved through an area, SDG&E crews were on-site to assess damage to the utility's assets. As a result, 750 SDG&E employees, along with 203 neighbor-state mutual-aid personnel and, at peak periods, 78 contract electric crews and 129 digging crews, were deployed to perform the service restoration efforts. Service was restored for approximately 83,000 customers affected by the fire and SDG&E eventually replaced more than 2,170 utility poles, 338 transformers, and at least 35 miles of overhead electrical wire (Geier, 2009).

Four years earlier, after San Diego County's 2003 wildfires, SDG&E had refined a model for supporting the logistical components of establishing and supporting command centers. This model was ready for implementation during the October 21, 2007. SDG&E's electric restoration response to the 2007 fires was supported by teams of employees from the Fleet, Facilities, Environmental, Supply Management, Logistics & Warehousing, Fleet Services, Facilities, Real Estate/Land, Environmental, and Safety departments (Dulgeroff, 2009). These teams were tasked with supporting the logistical needs for electric construction crews allowing the construction foremen and supervisors to be available to perform their core competency of repairing or rebuilding the electric system.

Working in teams of approximately three people per shift, the support team employees were consumed for 10-15 hours a day for the first 10 days of the emergency. They had to respond to central points near the fire-damaged areas where they set-up command center camps to serve three meals a day. The command center sites included restrooms, shaded rest areas, water, ice, and snacks to all the crews who were working 16-hour shifts (Dulgeroff, 2009). In addition, the command center sites needed mobile offices with internet connectivity (often via satellite due to the remote locations and/or damage to on-site power and

telecommunications connections). Also required were helicopter landing areas for hard-to-access, power pole replacements, water trucks for dust mitigation in the rural settings, mobile radio repeaters, and dedicated space for all the materials to be staged for the crews' use.

Preventative environmental checklists had to be followed at the rural sites. Straw wattle to prevent run-off, steel shaker plates to keep the vehicles from tracking loose dirt out onto the streets, and traffic control where the extra traffic related to the command center made an impact to normal traffic flow at the entrance were all required. Sites that were designated just as material lay-down locations, still needed restrooms and trash containers (Dulgeroff, 2009).

The region's basic communications infrastructure was not impacted by the fires, therefore alternate communications systems were not needed in the 2007 firestorm. It is timely to note however that emerging technologies leveraging communications devices already being used are being tested for response to emergencies impacting infrastructure. This new type of infrastructure-less wireless network, such as Georgia Tech's LifeNet model (Wilson, 2005), which is formed out of consumer electronic devices such as laptops or smart phones could have great utility in disaster scenarios impacting the traditional means of communications.

Using consumer devices such as smart phones and laptops to remove dependence on a company's local network infrastructure and data center could also be addressed by cloud computing.

In SDG&E's 2007 response, the team members used cell phones and laptops with air cards to track all the support activities and items for command centers, on spreadsheets that were emailed back and forth to the manager leading the command center efforts. This enabled them to track the logistics of all command center sites in a consolidated manner. Each day the team members participated in two conference calls with their counterparts, during which they were given updates from other SDG&E departments supporting the logistical efforts.

Observed Issues

The SDG&E team members who were serving as business solutions liaisons (BSLs) between the construction supervisors leading the restoration and rebuilding efforts of the crews, and the departments that procure and oversee delivery of the material and services used to set-up the command centers, reported occasions when their requests for items needed for the command centers were not conveyed exactly, or

delivery was late. Other times requests were duplicated, or second and third calls were received from the providers to confirm if materials or meals were still needed, when the items had already been received. The BSLs' daily submittal of the tracking spreadsheet to the manager's administrative support required a significant consolidation chore and lacked real-time status. For example, an impact of the spreadsheet's lack of timeliness was that if the BSLs needed to track something more timely than information from the afternoon before, they would have to participate in both conference calls each day, despite other tasks they might have been performing. Additionally, the BSLs needed to take their own notes as to what each command center team was reporting during the calls. Then, the spreadsheet combined with their handwritten notes provided them with more detailed information, but resulted in an abundance of paper. Further, the daily consolidation of spreadsheets from 17 different command centers contributed to the chance of errors being made. The possibility of achieving efficiencies through a more real-time method, rather than paper forms, repeated consolidation of emailed spreadsheets, and email requests first arose during the type of miscommunication reported above. This suggested an opportunity for investigation of a more real-time approach to handling the logistics related to the emergency response.

The rush to procure water, meals, tents, lights, portable bathrooms, and mobile offices is all performed in competition with other responding agencies in the region, public and private-sector. Any lag in response time could present the loss of the opportunity to obtain what is essential. Because of that competition for scarce resources, the first five days of a response are the most time-sensitive. Consequently, the potential for errors in the spreadsheets could have represented a loss of needed resources.

Research discusses the range of spreadsheet errors from calculation errors, to one that is more germane to this study, errors in data quality. Caulkins et al. (2005) cite these errors in data quality as one of three typical reasons that contribute to undetected errors in an alarming "91 percent of spreadsheets" (p. 22). These authors contend that a simple task such as a "bad sort can destroy the integrity of a row, or a mismatch of units" (p.23). This is supported by Panko's research in which he estimated 94 percent of spreadsheets contain errors (Panko, 2007). Therefore, it is clear that any solution must need no manual manipulation of the data such as is needed when using spreadsheets for database functions. An alternate solution must also have virtually no training-time requirements, since the employees assigned to the task in subsequent

emergencies will likely have no experience with the solution, nor would they have the luxury of time to learn it. The possibility of SDG&E changing its approach to command center logistics tracking as Commonwealth Edison and Duke Energy were able to do, merits further study.

After the 2007 fires, event-assessment and debrief of the command center support personnel included the subject being raised of the efficacy of spreadsheets and paper forms and the question of whether an alternate approach could have achieved greater efficiencies, especially in the areas where duplications and problems were encountered was posed. This study addresses the following research questions:

- What alternative approach would have enabled the teams working on the command center effort of emergency response to have easier-to-use, faster-to-access data?
- What solution would include the capability to store basic command center requirements from previous emergency responses to save time in addressing the first or most crucial items needed during the next emergency?
- What resiliency could be built into command center logistics tracking in case the company's network was rendered inaccessible at the same time as command centers were needed for service restoration activities?

Therefore, if SDG&E's electric or gas system was damaged by terrorist activity or another natural disaster with equal or greater severity than the firestorms of 2003 and 2007, tracking the command center logistics could become exponentially more difficult proportionate to the severity of the disaster. An alternative solution designed for easy access by users in multiple areas could enhance the support of the logistical efforts to bring the region's critical infrastructure back to normalcy in the most effective manner possible.

This study is designed to investigate the possibility of an alternate, multi-user approach, in order to improve accessibility or timeliness of information in a further refinement of disaster response tools. Results could aid decision-makers in their planning for subsequent emergencies. The present body of knowledge will be expanded by the study of converting from spreadsheets and paper forms currently used for some emergency management activities to more effective tools of response.

Post Wild Fire Analysis

After the Southern California fires of 2003, the Sempra Energy utilities' vice president of Business

Solutions, and Directors leading the support-type departments of Supply Management/Logistics, Fleet Services, Facilities, Real Estate/Land, Environmental, and Safety, formulated a program to further enhance their support to field operations areas in their response to emergencies. That new program was enacted for the first time during the 2007 Southern California fires. Under a dotted line reporting relationship to a manager responsible for all command center and staging area sites, "Business Solutions Liaisons" (BSLs) fulfilled a strategy that was designed to provide them as central points of contact. They were to interface between the operating centers' field operations and SDG&E's high-level central coordination and communications Emergency Operations Center (EOC), during emergencies that necessitated the set-up of staging areas and/or crew deployment areas. The BSLs were selected from a qualified pool of employees from the support departments, and based on their availability to respond to remote locations for ten-hour shifts. The BSLs were to be a visible presence in the field to facilitate proper two-way communications between field operations groups, the support departments, and the EOC, where requests would be received and dispatched to the proper responding support departments. The BSLs were intended to be the "one-stop-shop" for all requests instead of field supervisors having to make requests of many areas for their needs (Dulgeroff, 2009). The BSLs are not examined in this paper as a population. Their data output, however, is the sample examined.

The BSL program would be activated under certain conditions including:

- The utility experiences a major event
- The EOC is activated
- One or more off-property staging areas are needed
- It is requested by EOC staff

The BSLs had to be ready to mobilize at the beginning of an event through response and recovery. They were to engage with operating groups and coordinate with existing emergency response systems. In addition, the BSLs were to be familiar with field operations activities, be prepared for inclement weather, and be field-ready.

Teams of two BSLs were assigned to each location to cover two shifts per day. Sites were determined by identifying areas where the utility's system had sustained significant damage, for economies of adjacency in location decisions. If there was suitable land, and the area met strategic placement guidelines, a command center was located there (Dulgeroff, 2009).

In the first three days of the emergency, the Facilities department was activating its baseline set of plans, to achieve the earliest response to the expected

need for some type of field command centers or staging areas. Therefore, they already had contingency plans in place for rapid procurement of several large tents to house the resting and dining functions for the emergency response, generators, lighting, drinking water, catering, and portable sanitation services. As soon as they reported to their assigned command center locations with their laptops and air cards, cell phones, and personal protective equipment, BSLs checked-in with the construction supervisors to receive any logistical requests and support them in their core mission of directing system repair for service restoration of the utility system.

As the emergency unfolded, appropriate numbers of utility personnel, mutual assistance crews, and contract construction company crews were deployed to repair damaged segments of the system (Dulgeroff, 2009). The BSLs were apprised by the construction supervisors, of the crew size increases or decreases, as work progressed across the damaged areas, and as mutual assistance crews arrived. The command center needs were adjusted depending on that crew movement (Dulgeroff, 2009).

In order of priority, meals, water, ice, and sanitation facilities were the most important of the many things needed at the command centers. Shelter (tents), electricity, portable offices, internet connectivity, and garbage containers and garbage collection were next in order of priority. Following in priority were a fuel tanker to refuel the crew trucks and a pad for a helicopter to land, including a water truck to mitigate dust from the helicopter and the vehicle traffic.

As soon as the BSLs reported to their assignments, they were to review the template documents in their binders, time permitting. There were often requests and/or people waiting for the BSLs as soon as they got to their locations, and the BSLs provided rapid response and follow-up on all requests. The One-Stop-Shop was an exceptionally successful response model because the construction supervisors' needs were continuous and the BSLs execution of the ordering and tracking was a better use of company resources.

It quickly became apparent that the paper request forms in the binder were unworkable, for two main reasons. The forms were meant to be handwritten, then faxed to the EOC representative for that request category, however, there were no fax machines available, at least in the first several days of the emergency. Further, the forms required name, date, and time information. The natural inclination of the BSLs was to call the EOC representative and initiate the request via cell phone call, then complete an email note with the same information as a written confirmation, and for ease of follow-up. The email notes automatically recorded name, date, and time

information, and the BSL added the other shift's BSL in the carbon copy line. Early in the process, the paper request forms served as helpful visual cues for the details that needed to be included in the phone and email requests, but beyond that were hardly used.

Similarly, the paper BSL Service Request Log was viewed as inconvenient given the Sent Items feature which saves sent-email in a folder in the sender's Outlook program. Not all of the BSLs used this paper Log knowing their Outlook Sent Items function captured and archived them automatically and more permanently in case the information was needed at a later time. Given that the other shift's BSL had been copied on any emails that alternate shift BSL did not need to review the paper Service Request Log to ensure smooth transition of information.

Findings and Data Analysis

What alternative approach would have enabled the teams working on the command center effort for emergency response to have easier-to-use, faster-to-access data? What solution would include the capability to store basic command center requirements from previous emergency responses to save time in addressing the first or most crucial items needed during the next emergency? What resiliency could be built into command center logistics tracking in case the company's network was rendered inaccessible at the same time as command centers were needed for service restoration activities?

The 2007 Southern California fires damaged a large amount of San Diego County's territory including, in some areas, SDG&E's means of delivery of electric service, its poles, wires, cable, and transformers (Dulgeroff, 2009). SDG&E coordinated a full-scale effort to restore service for its customers as soon as possible. "To provide forward support closer to the actual field locations where the bulk of the repair and restoration work was occurring, SDG&E established 'command centers' and 'staging areas' in strategic locations" (Geier, 2009, p. 14). Establishing and maintaining the command centers and staging areas to support the crews in their restoration efforts, and ultimately closing them down, involved approximately 56 employees from supporting departments, for approximately three weeks in a significant logistical exercise (Dulgeroff, 2009).

The process began with: (1) baseline requirements needed for a command center or staging area, (2) personnel assigned to the location to be the points of contact, called BSLs, and (3) the BSLs' laptop computers with air cards for internet connectivity, the BSLs' cell phones, a master spreadsheet to track all the

details of all the command centers and consolidate them into one view, and paper forms on which BSLs could make requests for items needed at the sites. The spreadsheets did not look at the causes of the emergency, but helped manage the responses.

The lead author, a team lead of the SDG&E supply chain systems team, served in the BSL capacity. The people who received the requests and information from the BSLs and fulfilled them were support department representatives manning their specific EOC positions. Each EOC position was staffed around the clock at the beginning of the emergency, and as appropriate later in the response, was reduced to 16 hours per day of coverage.

The BSLs received all the requests associated with taking the command centers from their baseline configuration to fully-functioning field operations support, by working as the interface between the construction supervisors, the EOC representatives, and on occasion, directly with the vendors. The defined method for initiating a request for materials or services was in the library of paper forms.

In practice however, instead of using the paper forms to initiate requests, there were two preferred methods by which BSLs sent requests to the EOC representatives. The first method was via cell phone call. The second method was via company email which was available via air card internet connectivity and VPN computer network access. These emails were often written follow-up to the initiating phone call. Also, since they were accessing the network via VPN, all internal drives and intranet pages and systems normally available to BSLs were accessible. The EOC representatives were on-site at SDG&E's company headquarters location, and had the full company network available to them and received BSL email communications in that manner.

The main tool used to handle the command center logistics effort was a spreadsheet. The spreadsheets used for this study are three samples of the daily iterations of the 2007 Firestorm command center and staging area consolidated information. All of the categories represented essential items needed to support response to the emergency. Many of the BSLs' actual practices did not include filling-in the paper forms, which meant the paper forms provided in the binder went unused. The service request log in the binder was also not used by the BSLs as they preferred the daily-updated spreadsheets that conveyed the entire command center landscape. The spreadsheet in its consolidated form was the most significant tracking output of that effort. The main benefit of the spreadsheet was the ability to track, albeit a day later, the logistical details of the command center, which included upward reporting to and by the manager.

This information was kept current by the BSLs completing and emailing the spreadsheets back to the manager after the afternoon conference call, for his administrative support's updating. The inherent inefficiency of its manual consolidation prompted the research questions.

A consideration of efficiencies to be gained and opportunities to track more categories of information, if needed, might reveal a new structure for the process, using an alternative approach to the paper forms and the spreadsheet. Consequently, the analysis of efficiency of the spreadsheets compared to real-time access to data, might include a new technology or a combination of several. An examination of the details of forms on smart phones, dashboards, blogs and wikis, and cloud computing would be timely, as SDG&E continuously strives for improvement of its crisis response.

Discussion

Based on the data resulting from SDG&E's 2007 Firestorm command center support response analysis, two hours a day of conference call attendance, paper form requirements, and editing of the spreadsheet by each BSL team, indicates opportunities to improve efficiency exist. Several possibilities for alternative approaches to command center logistics tracking are growing in use and popularity. To address the first research question on what alternative approach to emergency response logistics tracking would be easier-to-use and provide faster access to data, rendering forms on smart phones in replacement of paper forms, blogs for BSLs to convey new situations or information they encounter, via a posting on a webpage, making it readily searchable for the next crisis, wikis, which can capture blog information of a more formal or permanent nature to document processes or procedures, and dashboards as a means to display the real-time, consolidated, command center information, links, and metrics are suggested.

The use of a database as the backend data repository supporting what is displayed in dashboards related to the second question, and the concept of cloud computing related to the third research question will be discussed later. This combination of alternatives incorporates the concept of building resiliency into a company's activities supporting critical infrastructure response work, as well as reducing duplicative or outdated methods. It also can be viewed through the lens of the expanded crisis response system model (Jennex, 2004). The expanded system encompasses more than the basic components of database, data analysis, normative models, and interface. Enhancing

the model includes the addition of trained users (where users are personnel using the system to respond to or communicate about the emergency and consist of first responders, long term responders, the emergency response team, and experts), dynamic, integrated, and collaborative (yet possibly physically distributed) methods to communicate between users and data sources, protocols to facilitate communication, and processes and procedures used to guide the response to and improve decision making during the crisis.

This expanded crisis response system model is applicable to the discussion of combining alternatives in order to better respond to the logistics tracking activities of SDG&E's emergency response. Specifically, the dashboards fulfill the model's condition for a dynamic method of communication, based on the real-time nature of the information received and displayed. The potentially constantly updated information supports the optimum display to users of what is residing in the underlying data sources and, further, to non-users such as executive teams, and decision-makers. The dashboards also fulfill the model's component of integrated and collaborative protocols by their attribute of displaying multiple types of information from multiple sources or contributors that would not normally be displayed together in a single view, or viewable by so many different parties. Additionally, the nature of the field operations and the EOC functions being physically separated conforms to the model's almost-certain distributed teams, sites, and means of communications.

The sometimes duplicative activities associated with the BSLs' use of paper forms and follow-up phone calls, and the time-consuming consolidation of that information in a spreadsheet with limited visual display characteristics, implied one or all of these alternatives may have efficacy in improving BSL-related data output in subsequent emergency efforts, as supported by the Jennex expanded crisis response system model. The result of analyzing enhanced concepts to the command center tracking needs, suggests further study of forms on smart phones, and dashboards connected to a robust back-end database already populated with baseline data as a starting template to save time, residing on remote servers in a private cloud. A site linked to the dashboard on which any participant in the command center effort could blog about any special experience for sharing with the other team members would be timely as well as easy to access. Problems or issues discussed in the blogs and successfully addressed, could be elaborated upon or documented in a more formal and thoroughly developed way and posted as a wiki, as a more permanent and searchable archive. The need for resiliency in case of unforeseen inaccessibility,

suggests the use of private cloud computing, which would result in a virtual, secure, remote location for SDG&E-related command center activities to be developed, housed, and delivered. That need for secure software and data is important because of the proprietary nature of the information. Therefore, a practical solution to help the utility in case of a catastrophic loss of its computer network might include private cloud computing. Possibilities of technological alternatives other than these may be suited for transforming the spreadsheets and the paper forms, and displaying command center logistics however, the intricacies of the related technology need to be addressed as further suggestions.

The viability of these technologies in support of alternative systems for crisis response is derived from Jennex and Raman (2009). The forms on smart phones, blogs and wikis, cloud computing, and the dashboards similar to those developed by SDSU's Visualization Center for flu tracking in San Diego County when implemented together, can all be considered components in the fusion of KM systems (Jennex and Raman, 2009).

Filling out paper forms and completing the spreadsheets was actually just the manual assembling of a list of data in columns and rows. It was not a meaningful transfer of ideas, needs, and information. When ideas, needs, and information are assembled without further requirement for consolidation or user adaptation, and then easily rendered visually, it results in expedient crisis response through impactful visual cues and a more efficient transfer of knowledge.

The implication is the tacit knowledge from BSLs' previous experiences can not be appropriately conveyed in a single file when the information is simply housed in a spreadsheet's columns and rows format. However, the multi-dimensional, graphical layering, and photographic images displayed in a dashboard format heralds the emergence of knowledge transfer that would benefit the evolution of SDG&E's emergency response model. Blogs to capture BSLs special experiences or issues, and wikis to more permanently archive the blog posts that lend themselves to formal processes and procedures, provide a searchable, easy to access forum for command center participants' specific information, and should be included as links in the dashboard. Handling the knowledge in support of crisis response in this manner substantiates the Jennex and Raman (2009) assertion that, decision makers, when under stress, need systems that do more than just provide data, they need systems that can quickly find and display knowledge relevant to the situation in a format that facilitates the decision maker in making decisions.

Implications and Recommendations

The research related to the spreadsheets revealed that they performed in an adequate manner based on the fact that the command center logistics tracking was generally accurate and the consensus among the interfacing groups was that the command center model performed very well. However, the lag time in displaying updated information on the distribution of the crews across the command center landscape during a day, and how that impacted meal counts which, potentially dramatically affected the crews' perception of well being, can be surmised due to the manual consolidation effort necessary to keep spreadsheet data current. The literature validates the significance of the crews' perceived well being as having substantial importance.

Relative to the discussion of the crews' well being, a tangent factor of the BSLs' efforts in the command center support was their stated feelings of satisfaction related to their accomplishments, as discussed in a BSL debrief meeting in November, 2007. The perceived usefulness of their efforts and their feelings of self-efficacy gave an indication of how likely BSLs would be to embrace alternative approaches to the work if it meant further improvement in their response to a crisis. While this relates to implementing knowledge management systems in support of crisis response (Jennex and Raman, 2009) it must be acknowledged that the responsibility for efficient and timely restoration of essential services is still a mandate from the federal government as codified in HSPD7. Despite SDG&E's culture of dedicated restoration activities, the BSLs' satisfaction in support of the company mission, or the opportunity to leverage computer technology and knowledge management systems to enhance the logistical support, the restoration activities would still be required by the federal government even in the absence of those company requirements and employee satisfaction drivers.

It also should be recognized that there could be a scenario when the normal network systems for achieving compliance with HSPD 7's requirements would be completely interrupted. In the event of a loss of SDG&E's computer network infrastructure, an alternative to the company network would be needed to handle the on-going restoration tracking efforts. One alternative to the traditional and local company network would be via cloud computing.

In the event SDG&E's computer network was rendered unusable, whatever applications were needed for the command center response could be housed on virtual servers in the cloud, and accessed via the internet, likely through wireless connectivity such as the BSLs' air cards. The implication is SDG&E could

continuously access its disaster response support tools if they were housed and delivered outside the company network. The security aspect would be addressed by using the cloud computing model known as the private cloud, in which processing, storage, networking, and the application, are via an intranet, allowing for user authentication, and encryption of the company's proprietary data.

Computing via the cloud also allows for applications to be used on a pay-as-you-go pricing schedule (Vanmechelen, et al., 2006). This would allow the cost of an important emergency response tool, after its initial development costs, to be borne only at the time the company is experiencing an emergency. Responding to emergencies often carries great costs, some of which can be recovered in rates if SDG&E's governing regulatory agency grants such a request. Matching the costs of a pay-when-used type of emergency response support tool to the infrequent occasions of emergencies impacting SDG&E's critical infrastructure, supports a position of careful stewardship of costs the company will eventually request to recover. Further, using cloud-based tools to house an emergency response logistics tracking application securely outside SDG&E's territory and having it be accessible via any internet-based connection along with VPN, provides a resilience to catastrophic wildfire- or earthquake-caused network destruction that would interfere with tracking of, although not halt, SDG&E's restoration activities in the field.

Analysis of the manual, and not-well-used paper forms for BSLs to send requests to the EOC, demonstrated the need for an alternate request method. As was demonstrated by actual practice, phone calls and follow-up emails were preferred to the paper forms. However, the email was duplicative to the phone call, which suggests a less-than-optimal use of the BSLs' time. The rendering of a paper form for display and user input on a smart phone has potential utility as the technology to replace the paper forms for command center logistics requests.

Data initiated by the request is needed to execute the activity and provides the EOC recipient with record of the exact details needed for accurate fulfillment, almost always better than a phone call request, but usually not faster. Yet the BSLs all had cell phones and continuously made requests initiated by phone calls then followed-up with emails for solid confirmation. An alternative is using a smart phone with a form accessed from the phone's embedded memory. The efficiency of using the hand-held portability and instant communications of a cell phone, while having the accuracy and full detail inherent in a form, can both be achieved with this technology. The

electronic forms housed in the smart phones' memory could also be available in a library of request forms linked on the dashboard, as a secondary and back-up location to the smart phones. The practices of the BSLs in the field imply this alternative merits further investigation and possible piloting during future SDG&E emergency drills.

Another implication for future research addresses the need to experiment with the dashboard as a more informative alternative for the current spreadsheet data and to house links to other BSL-needed information. A test model would include a dashboard being provided to the BSLs, their decision-makers, and related support departments for further determination of the efficacy of the technology. The user requirements of both dashboard and cloud computing would be structured by the technical staff at SDG&E to determine whether cloud computing and dashboards are viable alternatives to replace the current emailed spreadsheet.

The spreadsheet as the most significant tracking output of the BSLs' 2007 efforts is important when considering how such a single, relatively simple file was the source for tracking a great deal of valuable SDG&E-owned or rented assets, providing the manager with the ability to report to the EOC and the Executive team, the extent of the command center support of field operations and his decision-making related to consolidations of sites, or needed geographical changes, particularly while the fires were still burning. Considering those substantive uses of the spreadsheet, the lag time in the data's accuracy due to the need for consolidation, indicates the audiences could be better served as more real-time technologies become achievable for this specific purpose. Furthermore, the recognition of the potential need of other categories and/or sources of information implies the spreadsheet format was already at the limit of its utility. The need for a tool with the ability to display data in a visual, real-time format, with links to additional helpful or related sources of information such as BSL-related blogs and wikis, seems a likely area for future study, since dashboards provides internet-browser display of many categories of data from potentially many sources.

Dashboards also provide for understanding of performance indicators of importance to a specific audience, by summarizing them and often displaying them by graphical icon. The summarized data displayed in a dashboard can be the starting point to drill down to their detail. Conveying the data in a summarized, graphical way represents a significant, behind-the-scenes effort of collection, consolidation, and presentation of the data that starts to transfer tacit knowledge when the consolidation allows for decision-

making based on the whole picture that is drawn by the dashboard. Dashboards support two important points made by Turoff, supplying the best possible up-to-date information is critical to those whose action may risk lives and resources and that an emergency response information system must be an integrated electronic library of external data and information sources (Turoff, 2002). The data in SDG&E's command center tracking spreadsheet has the potential to become enhanced decision-making information and therefore knowledge that can be applied by its users through the use of baseline data from past command center experiences to respond to a present emergency.

Using a dashboard displaying data taken from the spreadsheet categories in a more actionable manner could enhance decision-making or at the least, readability and timeliness. The summarization and display of all of these types of information sources in a single dashboard enables viewers to drill down to access other websites, company intranet pages, participant blogs, related wikis, detailed data from maps and databases, and have it all accessible real-time. It would be a significant enhancement to the ways this information was available to SDG&E's emergency response support teams in previous emergencies. This practice of selectively applying knowledge from previous experiences during turbulent moments of decision making, to current and future decision making activities with the express purpose of improving the organization's effectiveness, would be possible via a KM system (Jennex and Raman, 2009) such as a dashboard along with its underlying means of delivery.

Conclusions

This paper proposes using knowledge to drive an alternative to SDG&E's paper request forms for command center needs, and suggests the use of request forms rendered on smart phones assigned to the BSLs for the duration of the effort. In addition, the development of dashboards, including links to command center participant blogs and wikis, is suggested as an effective alternative to spreadsheets to track the command center logistics, and provide easy to access information by means of links. Finally, the use of cloud computing as the development platform and host of an SDG&E dashboard application is recommended as a timely evolution to a KM system approach to achieve logistical tracking efficiencies.

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