Contributing Factors of Incident Command System to Information Collection and Sharing in Disaster Response Operations
— Comparative Inquiry on ICS and Non-ICS Response Models Using the Information Entropy Equation —

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Abstract
Japan is the only advanced nation in the world that has not incorporated a standardized response management system, such as an incident command system (ICS), in its response operations. To quantitatively demonstrate the potential value of incorporating a standardized response model, a comparative analysis of the impacts of the ICS response model on information collection and sharing was performed. Participants were engaged in 8 prescribed scenario-based rescue drills involving an incident command post and simulated hospital, allowing for the collection of radio communications data. This data was analyzed to determine the means estimate information value (Bits) using the Shannon’s Information entropy. The results showed that participants using ICS (+) at the incident command post had more information values of 1.08 in 5 to 10, 0.83 in 10 to 15 and 2.49 hits in 15 to 20 minute interval than the group without, there were significant differences in the said between ICS (+) (M=6.9, 8.72 and 9.88, SD=0.34, 0.12 and 0.42 respectively); t(14)=7.52, p=0.001, t(14)=15.7 and p=0.001 respectively. ICS (+) at the receiving hospital had more information values of 1.26 and 2.14 (M=5.45 and 7.82, SD=0.46 and 0.40 respectively); t(14)=5.81, p=0.001 and t(14)=11.45, p=0.001 respectively. This data supports the ICS response model may enhance the information collection and sharing activities in emergency operations.

KEY WORDS: Incident Command System, information management, information entropy analysis, disaster

1. Introduction
Japan is centrally located on the ring of fire in the Pacific, creating an increased risk of seismic based disasters such as earthquakes and tsunamis. These hazards can lead to a variety of secondary impacts that require specialized response. An example of this can be found in the unprecedented responses to the 3.11 tsunami (2011), which were made more complex for first responders when two nuclear power plants exploded in Fukushima. Incidents at nuclear power plants are not unknown in Japan and have historically been managed by authorities using existing response structures. However, authorities were totally unprepared for the magnitude of impacts caused by the March 11 earthquake and following tsunami. The unprecedented scope and severity of this event Justice Institute of British Columbia, Canada forced the Japanese people to give top prioritization to the improvement of emergency management structures and practices. To support these efforts, the Cabinet Office of the Japanese Government, the national office having responsibility over disaster management coordination, has examined the steps taken by other advanced countries to strengthen their own response with particular consideration given to situations where time and resources may be limited 2). Additionally, the broader Japanese government and affiliated universities have examined North American models of emergency management and their related support functions. Of particular interest was the Incident Command System (ICS).

ICS is a standardized, scalable emergency response system used to coordinate the activities of multiple responding agencies. ICS was developed in response to disaster management problems encountered in the 1970’s and 80’s forest fires in California. As the model has evolved over time, the adoption and use of ICS has spread across emergency response agencies in the United States and Canada.

In contrast, Japan’s existing emergency response model relies heavily on response models and structures that are aligned with Japan’s unique cultural history. These structures and practices are not nationally standardized but are locally defined, often in driven by a need to integrate the management needs of local authorities within the scope of
the Disaster Countermeasures Basic Act.

In practice, Japanese response organizations often respond to disasters by employing day-to-day business practices, which can lead to delays in decision making and information sharing. Further, the use of local, non-standardizes response models and practices in Japan impedes coordination and interoperability between response agencies. The result is a situation where each response group (e.g., fire department, police officers, paramedics, etc.) perform their own defined tasks with little multi-agency coordination and information sharing. Japan's approach to emergency management has been described as reactive and fragmented and can be seen as over reliant on technological advancements to mitigate hazards and neglecting the development of shared response models.

In recent years, the Japanese government has implemented a variety of improvements to the disaster response programs employed at different levels of government. These improvements have included integrating citizens' group participation into risk management and preparedness programs as well as the expansion of mutual-aid agreements which support multi-agency coordination during response. However, these changes have not resulted in significant improvements. This is evidenced by the similarity in lessons for improvements in Japan's response model identified after the 1995 Hanshin-Awaji Earthquake and the 2016's Kumamoto Earthquake. Despite the implementation of improvements to the disaster response model following the Hanshin-Awaji Earthquake, persistent response challenges were seen in the response to the Kumamoto Earthquake. In the wake of the Kumamoto Earthquake, there were challenges in activating some Emergency Operations Centers (EOCs) in main council buildings due to physical damages to their structures. This resulted in delay in response operations Alternative sites for the EOCs, such as community centers and gymnasiums, escaped severe damages but were not equipped to function with the same capability as primary EOC facilities. During the earthquake response, information, particularly in relation to the response needs, was not referred to the EOCs in a timely and effective manner due to disruptions to land-line and cell phone networks. This was later addressed as phone companies provided limited temporary, alternative networks in damaged areas. Further, convergent volunteers (citizens spontaneously offering assistance to the government and/or response agencies) were not well coordinated in the early stage of the response efforts due to initial disorganization of local authorities. While the Kumamoto Earthquake demonstrated that response problems persist, this is not to say that they cannot be addressed through the redevelopment of response models – a process that took place in the United States with the creation of the ICS response model. To that end, the model has been adopted by a number of countries, either in part or in full, with ICS concepts being integrated into their related national incident management systems. However, Japan has not adopted formally standardized response model, ICS or other, meaning the adoption of a national standard for incident response is one of the final areas where Japan needs to implement systematic improvements.

The authors posit that the ICS principles, structures, and support functions would reduce issues related to management and coordination during the early stages of an emergency response as well as strengthening Japan's overall response management efforts. In order to gain a deeper understanding of the potential for the ICS response model to support Japanese governments and responders, quantitative data depicting its potential effectiveness is required. In general, the evaluation of the ICS response model has focused on subjective assessments, making use of questionnaires and interviews and soliciting input from ICS practitioners. However, Japanese governments and emergency responders require quantitative data on the efficacy of the ICS response model in order to make evidence informed decision around its adoption effort. The reliance of ICS researchers and practitioners on subjective, qualitative assessments has left a gap in available data. As Cole, et al (2000) pointed out previously that "there has never been a comprehensive performance evaluation of the (ICS) system". Further, Chang (2017) identifies that "the debates of the effectiveness of using the ICS have never stopped″. The lack of quantitative data available to support robust discussions has been one of the causes for the relatively muted debate within Japan on the effectiveness of the ICS response model.

With this in mind, this paper will explore the effectiveness of specific aspects of the ICS response model with a goal of identifying data to support future discussions. As the ICS response model covers a spectrum of managerial and coordination activities, this paper will narrow its focus on the benefits ICS offers in strengthening information collection and sharing. This will be done by measuring the differences in the amount, or value, of information shared between the participating emergency response teams. In this model, selected teams will employ one of two response models during a series of emergency response drills. One set
of teams will employ the ICS response model; the second set will employ current Japanese-based models of emergency response. The Emergency response drills were conducted at the Chiba Institute of Science (CIS). The aim of these drills was to examine the degree to which use of ICS practices would enhance information collection, sharing and communications interoperability amongst participants representing the Japanese emergency management community.

2. Japanese response model in information collection and sharing

As previously mentioned, Japan maintains a unique approach to disaster response that does not incorporate internationally recognized models. In general, Japan follows a fairly rigid mechanistic structure in both public life and private sectors (more specifically in larger corporations) in terms of dealing with a disaster. Implementing broad changes to Japan's disaster response structure would likely be influenced by a variety of factors, including culture, values, and social systems that shape how public sector agencies plan and operate in emergencies.

In a typical Japanese governmental disaster response program, the primary response organization is found at the lowest government level and takes the form of a village office, township, or municipality. Subsequent levels of government provide support and strategic guidance to lower levels of government. Each level of government relies heavily on the Disaster Countermeasures Basic Act, a foundational document that is referenced by all governmental agencies in Japan, in developing specific aspects of an emergency program.

Following Japanese law, all government offices are required to develop and maintain their own disaster management plans. These plans describe the various responsibilities of government and emergency responders during an emergency. These plans are also aligned with the known scope and characteristics of local hazards, which are identified and evaluated during an annual process of risk identification and hazard appraisal. In the Japanese model, local authorities are provided with considerable discretion to determine the specific emergency response actions that will be taken during a disaster - so long as the emergency plans and related program elements are aligned with their legal requirements. However, local authorities are accountable to the prefecture government, and subsequently the national government, regarding their emergency actions. Combined with the need to maintain alignment with legislation, local authorities are placed in a situation where is it difficult to adopt innovative, and possibly untested, practices. The rigidity of this top-down relationship creates a professional culture that values consistency with past practice versus the adoption of new and/or innovative practices. The result is a system that cannot readily avoid repeating past response weaknesses and failures – particularly in areas such as information sharing command, and control.

A practical example of communication challenges can be seen in a hypothetical traffic accident that involves hazardous materials. In this scenario, each responding agency knows their role: police officers respond to the accident and setup a perimeter, the fire department supports the rescue of victims and the cleanup of the chemicals, and paramedics support the transport of the injured to hospital. However, what is missing in this model is the overall multi-agency coordination at the scene. The lack of coordination means the same work may be performed multiple times or missed altogether. For example, in this scenario, each response group will have started collecting incident information that directly informs their own response operations. Due to the lack of multi-agency coordination, information sharing between agencies cannot be easily performed. Communications challenges can range from a lack of interoperable radios, the use of agency-specific language, and differing information needs. In practical terms, this can lead to series of issues: response agencies not being aware of what other agencies are doing; eye-witnesses being interviewed multiple times by different agencies; information important to one agency may be discounted or ignored by another; information may be relayed to higher levels of government without first being vetted or confirmed by other agencies. Additional challenges can include: the creation of multiple incident command posts (a central coordination hub for one or more agencies) that are redundant or that work at cross-purposes; challenges integrating non-traditional agencies into emergency response (such as transit- and telecommunications companies); and a lack of planning around the transition from response to recovery.

These challenges extend to the municipal emergency operations centers (EOC) – government offices that support site-level response as well as addressing community impacts. In the municipal EOC, liaison and/or information staff from different agencies are usually present to facilitate information sharing. However, these staff rely on status report produced by agency-specific first responders at the site level. These reports will provide a narrow view of the
incident, specific to the observations of a single agency. The current Japanese method of information collection and sharing is complicated by the use of agency-specific language and communications equipment, creating a situation where EOC staff must invest significant time and effort to develop an overall understanding of the emergency event (a big picture). The challenges with information sharing at the site level exacerbate this issue.

As mentioned earlier, challenges with information sharing during an emergency have been a long-standing issue that has not yet been comprehensively addressed. The post-activity report of the Yamanashi prefecture government following the 2016 Kumamoto earthquake describes unacceptable delays in emergency response operations and confusion in information collection and sharing\(^{(10)}\). These same issues were identified 21 years earlier in the lessons learned from the 1995's Hanshin-Awaji earthquake\(^{(11)}\). It is evident these particular challenges are not being addressed by Japan's current response model.

3. ICS based Information Collection and Sharing

In this section, we will describe the use of the ICS response model in the context of British Columbia, Canada. The provincial government of British Columbia has adopted the ICS structure and practices as a fundamental component of the provincial emergency response management system\(^{(12)}\). In a hypothetical emergency scenario, emergency responders arriving at a scene would attempt to rapidly coordinate their actions. First, an incident command post (ICP) is established at the incident scene by the first arriving officer or responder. This individual would identify themselves as the Incident Commander (IC) by informing other responders and identifying the location of the ICP – typically an emergency response vehicle located a safe distance from the incident. All responding agencies, regardless of their organization, will then coordinate their actions under the single command. To clarify, each agency still maintains responsibility for their response duties, as well as control over their resources, personnel, and communications. However, emergency responders align and coordinate their work under the overall direction of the IC.

The IC may change over the course of the event, such as when a higher ranking or more experienced officer or responder arrives. During and following this transfer of command, the command-and-control structure remains in place, supporting the continuity of response operations.

The collection and sharing of information are particularly important at the IC. Validated information is shared amongst all responders through the use display boards and shared written documents at both the ICP and EOC. To support information gathering as well as overall response operations, specific support and/or management roles are identified for specific responders. One of these roles is a Planning Section Chief who supports the gathering and management of information. This validated information can then be used by the IC to support the development of shared incident response plans that incorporate and coordinate the actions of each response agency.

Should the incident grow in scope or complexity, a local government EOC may be activated to provide additional support. The same information gathered at the ICP will be provided to the EOC. Additionally, information gathered by the EOC will be shared directly with the ICP. In this model, information is gathered and shared at both the IC and EOC allowing all involved personnel to have access to the same, validated information.

If information needs to be shared with higher levels of government, both IC and EOC staff can share information through a liaison officer, the EOC Director, or through liaison staff stationed in the EOC. If information needs to be shared publicly, a Public Information Officer (PIO) at the IC, EOC, or working together can provide information through a variety of communications channels. Federal level government agencies can also reach the PIO or a liaison officer and obtain information. This streamlined information sharing model supports the efficient sharing of validated and updated information.

4. ICS Evaluation

Comparing emergency response models is not a straightforward task. Each model will employ different structures and practices that can hinder a direct comparison. Additionally, quantitatively evaluating the effectiveness of a particular aspect of a response model is also a challenge due to a number of factors. Using ICS as an example: ICS is a method of coordinating people – to that end, research often focuses on the qualitative experience of practitioners. As mentioned previously, past evaluations of ICS have involved subjective opinions, often gathered post-event through informal interviews and/or questionnaires.

Second, many of the factors that influence the success of a response model are external to the model itself and may not be testable or repeatable. Finally, it may be difficult to delineate between practices described by a response model versus practices employed by a specific response agency.

The Japanese emergency management communities
value quantitative assessments of system effectiveness – particularly when being asked to make changes to traditional and shared models. While it would be difficult to identify a specific quantified value for the overall effectiveness of the ICS response model, it is possible to quantify the effectiveness of specific ICS systems over other models – in this case, a model of information management at the site-level.

5. ICS and Information Entropy

Well planned information management practices are essential to an effective and efficient emergency response. Information management involves the efficient collection of accurate information; the ongoing validation of information; and ready sharing of accurate information with personnel to support timely and appropriate decision making and establishing scene safety for responders and others.

On the surface, it may appear difficult to quantify these aspects of information sharing. One tool that allows for a quantitative examination of information management is the Information Entropy equation (Shannon’s Information Theory), which serves to quantify "the average amount of information needed to represent an event, drawn from a probability distribution for a random variable" (13). In other words, if the amount of information collected on-scene for situational awareness and prompt decision making surpasses a particular size, the Entropy equation can be applied to provide numerical value/amount that can be compared between ICS users and non-users. By employing this equation across different scenarios using different response models, a series of values/amounts can be generated and compared.

In order to apply the equation to these emergency drills, it was necessary to define the types of information and sharing modalities that would be used by participants. On-scene radio communications were identified as being the most readily observable and measurable form of on-scene communications as they are recordable and capture communications from individuals throughout the emergency scene.

6. Analysis Method

For this research, a series of identical drills were planned and conducted. The scenario for the drill was a natural gas station explosion requiring the rescue of multiple victims followed by the subsequent triage and transport of victims to a receiving hospital. The drills were designed by a team of retired fire officers with more than 20 years of command-and-control experiences in Japan. These retired fire officers also functioned as controllers of the drills, overseeing the response and monitoring for safety issues. A total of 8 drills were performed. The radio communication traffic was recorded during each drill to support the development of an entropy estimation (value/amount of information shared). Collected radio data was subsequently digitized, then transcribed into an Excel table. Each word of each radio call was identified to support morphological analysis. Following this, the probability of each words use and an Entropy calculation were identified.

168 students from the CIS Paramedic Course were recruited from 2018 to 2021 to take part in the drills, wherein they would simulate the response actions that would be taken by predefined response agencies. Students were divided into one of nine agencies: Fire, ambulance, rescue, police, natural gas company, telecommunication company, water department, electricity corporation and receiving hospital staff. Each simulated agency had one to three students simulating agency personnel for each agency, one person functioned as a leader with a radio device. These students were then divided into 16 groups, containing simulated representatives of each emergency response agency.

Comparable training was provided to each of the participants. Eight ICS (+) groups had taken a three-month long ICS-100 course, taught by the certified ICS instructor prior to taking part in the drills. The other eight ICS (-) groups attended a three-month long class covering the response methods used by Japanese fire departments.

During the drills, the ICS (-) groups were free to implement the practices and support functions found in the ICS response model, including the use of an incident command post; dynamic site-level information collection and sharing capability among responding agencies; uninterrupted and interoperable radio communications; one identified incident commander; an identified logistical support function; and clearly defined mutual aid agreements. The ICS (-) used the Japanese response method including the activation of separated command posts by different response agencies; potentially interruptible cell phone communications between the Fire command post and the receiving hospital; and non-interoperable radios.

The drills followed the same timeline and scenario for both ICS (+) and ICS (-) groups – see Table 1 and Table 2. However, one of the drill controllers would periodically introduce external conditions to both ICS (+) and (-) groups representing known real-world issues impacting operations.
and equipment. The first external condition was a lack of information sharing from various agencies on scene in the early response stage - approximately 3 minutes after the first response team arrived at the site. Then, approximately eight minutes into the drill, a cell phone outage between the Fire Command post and a receiving hospital occurred. This resulted in the hospital not receiving information about the number of victims to be transported or their triage status until later in the exercise. Additionally, the receiving hospital could not send messages to the Fire command regarding its ability to receive patients, resulting in a delay in transporting victims to hospital.

Table 1. Operational sequence for ICS (+)

<table>
<thead>
<tr>
<th>Seq.</th>
<th>ICS (+)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>119, reported</td>
</tr>
<tr>
<td>2</td>
<td>FD responded to scene</td>
</tr>
<tr>
<td>3</td>
<td>FD on scene</td>
</tr>
<tr>
<td>4</td>
<td>FD established ICP</td>
</tr>
<tr>
<td>5</td>
<td>Rescue &amp; EMS ops</td>
</tr>
<tr>
<td>6</td>
<td>Triaged, First Aid provided, ops continued</td>
</tr>
<tr>
<td>7</td>
<td>Transported, ops. continued</td>
</tr>
</tbody>
</table>

Note: Seq. indicates the sequences of each operational transaction as they happened. 119 is a location of receiving emergency messages from persons who reported the incidents. FD means the Fire Department. ICS indicates an incident command post. Ops. means operations in the drills.

Table 2. Operational sequence for ICS (-)

<table>
<thead>
<tr>
<th>Seq.</th>
<th>ICS (-)</th>
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<tbody>
<tr>
<td>1</td>
<td>119, reported</td>
</tr>
<tr>
<td>2</td>
<td>FD responded to scene</td>
</tr>
<tr>
<td>3</td>
<td>FD on scene</td>
</tr>
<tr>
<td>4</td>
<td>FD established ICP</td>
</tr>
<tr>
<td>5</td>
<td>Rescue &amp; EMS ops</td>
</tr>
<tr>
<td>6</td>
<td>Triaged, but could not send info. to hospital</td>
</tr>
<tr>
<td>7</td>
<td>FD sent messengers est. comm. at hospital</td>
</tr>
</tbody>
</table>

During this same timeframe, the ICS (+) groups activated a shared incident command post and began centrally collecting and sharing information from all participants via interoperable radios. The cell phone outage was also introduced to the ICS (+) groups but owing to their use of radios, it appeared not to have an effect on their field operations.

In order to confirm the ICS (+) and ICS (-) groups were following their respective response models (ICS versus traditional Japanese approach), a heatmap analysis was employed to show the locations of their activity using the average GPS coordinated and the level of activity intensity. For the heatmap analysis, each leader's average physical location was identified, with the number of staff working near their locations serving as a variable. The IC's location had a weighted value of 2 while staff were weighted to 1. This simplified the process of identify and tracking the IC's position during the drill. During this time, the Cystoscope software was used to conduct a network analysis of radio communications data to identify the type of response formation each group has made.

7. Results

Fig. 1 shows that the ICS (+) groups implemented an ICS response model evidenced by a higher level of interaction at a centrally located incident command post. On this heatmap, each response agency is plotted with a blue color dot to illustrate where they were primarily engaged in work during the drill.

Fig. 2 shows the response formation taken by the ICS (-) groups as they implemented the traditional Japanese emergency response model. Agency leaders set up their own command/coordination posts based on the proximity to the emergency. The heatmap shows that no central incident command post was established and that participants performed response activities at their respective command posts.

A network analysis conducted to identify if the participants formed groups that aligned with the ICS response model or the Japanese approach. Each node in the Figure represents the radio call signs assigned for the drills. Fig. 3 shows the ICP had the highest number of nodes and centrality values, demonstrating it served as a hub for command, control, communications and coordination of the site management and response operations. Also, the recorded data demonstrates that ongoing radio communication was maintained between the ICP and the receiving hospital. Based on this data, it can be concluded
Fig. 1 Heatmap of ICS (+) Average Teams' Locations and Activity Intensity

*Note.* Blue dots indicate geographical locations of leaders of each organization who were assigned to command and control. The redder color the location was, the higher command and control operations intensified. The heatmap indicated a single red color area in the drills with the ICS (+) response model.

Fig. 2 Heatmap of ICS (-) Average Teams' Locations and Activity Intensity

*Note.* The geographical heatmap shows the locations of higher intensity operational command and control activities when the ICS response model was not in use. The redder color the location was, the higher command and control operations intensified.

Fig. 3 ICS (+) Based Formation

*Note.* Green dots are radio call signs which were active in operational radio communications in the drills using the ICS (+) response model. Lines indicate radio traffic linkages identified in the drills. Red dots indicate the numbers of connecting radio operators.

The ICS (+) teams were implementation structures and functions typically associated with the ICS response model. Fig. 4 identifies the radio communications between participants in the ICS (+) groups. The data shows little to no centralization of radio communications was established at the scene. During the ICS (-) drills, a response team with the simulated natural gas company made use of cell phone communications, which means its node did not appear in the Figure. Also, the fire command post used messengers in the form of runners (people delivering messages on foot) to share and collect information with other agencies' coordination posts. Messenger communications are not captured in the Figure. Based on the independent operations of the agency command posts and non-interoperable radio communications there can be concluded the ICS (-) participants were following structures and practices typically associated with the Japanese response model.

Following the drills, the Information Entropy equation could be employed to measure the amount of information collected at an ICP [ICS (+)] / FD Command Post [ICS (-)] (Fig. 5, Table 1) and a receiving hospital (Fig. 6, Table 2). This was done through analyzing the recorded radio traffic. As shown, the participants using ICS (+) at the ICP had more information values of 1.08 in 5 to 10, 0.83 in 10 to 15 and 2.49 bits in 15 to 20 minute interval than the group without, there were significant differences in the said between ICS (+)
Fig. 4 ICS (-) Based Formation

Note: Green dots are radio call signs which were active in operational radio communications in the drills using the ICS (-) response model. Lines indicate radio traffic linkages identified in the drills. Red dots indicate the numbers of connecting radio operators.

Table 1. Information Values (Bits) Estimated at ICP

<table>
<thead>
<tr>
<th></th>
<th>5 to 10 min.</th>
<th>10 to 15 min.</th>
<th>15 to 20 min.</th>
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<tbody>
<tr>
<td></td>
<td>ICS</td>
<td>ICS</td>
<td>Diff.</td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6.58</td>
<td>5.83</td>
<td>0.75</td>
</tr>
<tr>
<td>2</td>
<td>7.54</td>
<td>5.93</td>
<td>1.61</td>
</tr>
<tr>
<td>3</td>
<td>6.96</td>
<td>5.93</td>
<td>1.03</td>
</tr>
<tr>
<td>4</td>
<td>6.29</td>
<td>5.55</td>
<td>0.74</td>
</tr>
<tr>
<td>5</td>
<td>7.13</td>
<td>5.93</td>
<td>1.20</td>
</tr>
<tr>
<td>6</td>
<td>6.91</td>
<td>5.54</td>
<td>1.37</td>
</tr>
<tr>
<td>7</td>
<td>6.85</td>
<td>5.93</td>
<td>0.92</td>
</tr>
<tr>
<td>8</td>
<td>6.96</td>
<td>5.95</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Note: ICP indicates an Incident Command Post. Diff. indicated the amount of information difference between the ICS (+) and (-). AVG indicates average value. SD shows standard deviation. Values are shown based in the time intervals of 5-to-10, 10-to-15, and 15-to-20 minutes.

Table 1 and Fig. 6 provide the information sharing values at the receiving hospital, illustrating information sent by the ICP/Fire Command Post. For the ICS (+), a failure free radio communications network was the primary method of communications while the ICS (-) used a cellphone network. During the drills, a simulated cellphone network failure was introduced around the 8-minute time mark. During this time, the ICS (-) fire command had to reestablish the communications with the receiving hospital, which likely reduced the average information value amongst the ICS (-) groups. This became increasingly evident later in the drill, as at the 15 to 20-minute mark, more than 2 bits of value difference was measured. The ICS (+) at the receiving hospital had more information values of 1.26 and 2.14 (M=5.45 and 7.82, SD=0.46 and 0.40 respectively); t(14)=5.81, p=0.001 and t(14)=11.45, p=0.001 respectively.

Fig. 5. Average Info. Values Comparison at ICP/FD Command Post

Notes. The figure shows the amount of information counted using the Information Entropy equation at 0 to 10, 10 to 15, and 15 to 20 minutes. The groups at the receiving hospital using the ICS response model tended to gain more situational information from radio communications than the groups without.

and ICS (-) (M=6.9, 8.72 and 9.88, SD=0.34, 0.12 and 0.42 respectively); t(14)=7.52, p=0.001, t(14)=15.7 and p=0.001, and t(14)=8.55, p=0.001 respectively.

Fig. 6. Average Info. Values Comparison at Hospital

Notes. The figure shows the amount of information counted using the Information Entropy equation at 0 to 10, 10 to 15, and 15-to-20-minute time intervals.
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8. Discussions

Based on the scenario, two distinct information gaps occurred between the ICS (+) and (-) at the ICP/Fire Command Post. During the ICS (-) drills, it appeared that agencies were not able to readily share information or access information other agencies had gathered. An example of this arose when a simulated traffic jam occurred, hampering the movement of rescue apparatus. In one ICS (-) drill, the fire command asked the on-scene police officers to help clear the traffic. This was done by sending a messenger on foot to the location where the police commander was located. The time involved in having messengers move between the command posts slowed response times. Quantitatively, an estimated 1.34-bit information value gap was caused by this delay.

In contrast, the ICS (+) located their fire commander at the ICP. The fire commander then coordinated centralized information collection and sharing from all participants on scene. The use of interoperable radio communications network simplified this process as well as streamlined the sharing of information. For example, when the issue of the traffic jam arose for the ICS (+) groups, the police were able to quickly direct their officers to clear the traffic by radio.

In general, interoperable communications and a central incident command post shared by on scene participating agencies may have positively impacted the initial information values at the ICP in the early stage of the drill. The data points to the ICS (+) groups having had specific advantages in terms of information sharing early in the drills, supporting prompt decision making.

The information gap between the ICS (+) and ICS (-) groups was reduced 10 to 15 minutes after the start of the drill. This may be due to improved information flow once the messengers were increasingly active and familiar with the site layout. However, the ICS (+) gained 1.56 bits more information at 15 to 20 minutes’ interval. This can be explained by the failure-free radio communications, providing a smoother information flow to the ICP and other nodes. The data also shows the ICS (+) groups had increased advantages in information collection and sharing.

8. Discussions

Based on the scenario, two distinct information gaps occurred between the ICS (+) and (-) at the ICP/Fire Command Post. During the ICS (-) drills, it appeared that agencies were not able to readily share information or access information other agencies had gathered. A clear example of this arose when a simulated traffic jam occurred, hampering the movement of rescue apparatus. In one ICS (-) drill, the fire command asked the on-scene police officers to help clear the traffic. This was done by sending a messenger on foot to the location where the police commander was located. The time involved in having messengers move between the command posts slowed response times. Quantitatively, an estimated 1.34-bit information value gap was caused by this delay.

In contrast, the ICS (+) located their fire commander at the ICP. The fire commander then coordinated centralized information collection and sharing from all participants on scene. The use of interoperable radio communications network simplified this process as well as streamlined the sharing of information. For example, when the issue of the traffic jam arose for the ICS (+) groups, the police were able to quickly direct their officers to clear the traffic by radio.

In general, interoperable communications and a central incident command post shared by on scene participating agencies may have positively impacted the initial information values at the ICP in the early stage of the drill. The data points to the ICS (+) groups having had specific advantages in terms of information sharing early in the drills, supporting prompt decision making.

The information gap between the ICS (+) and ICS (-) groups was reduced 10 to 15 minutes after the start of the drill. This may be due to improved information flow once the messengers were increasingly active and familiar with the site layout. However, the ICS (+) gained 1.56 bits more information at 15 to 20 minutes’ interval. This can be explained by the failure-free radio communications, providing a smoother information flow to the ICP and other nodes. The data also shows the ICS (+) groups had increased advantages in information collection and sharing.

Table 2 Information Values (Bits) Estimated at Receiving Hospital

<table>
<thead>
<tr>
<th>N</th>
<th>0~10</th>
<th>10~15</th>
<th>15~20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICS+</td>
<td>ICS-</td>
<td>ICS+</td>
</tr>
<tr>
<td>1</td>
<td>5.39</td>
<td>4.17</td>
<td>0.80</td>
</tr>
<tr>
<td>2</td>
<td>5.00</td>
<td>3.91</td>
<td>0.77</td>
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<tr>
<td>3</td>
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<td>3.70</td>
<td>0.71</td>
</tr>
<tr>
<td>4</td>
<td>5.56</td>
<td>4.12</td>
<td>0.71</td>
</tr>
<tr>
<td>5</td>
<td>5.58</td>
<td>4.17</td>
<td>0.90</td>
</tr>
<tr>
<td>6</td>
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<td>4.58</td>
<td>0.73</td>
</tr>
<tr>
<td>7</td>
<td>4.86</td>
<td>3.91</td>
<td>1.10</td>
</tr>
<tr>
<td>8</td>
<td>6.23</td>
<td>4.95</td>
<td>0.91</td>
</tr>
<tr>
<td>9</td>
<td>5.45</td>
<td>4.19</td>
<td>1.26</td>
</tr>
</tbody>
</table>

Note: HP indicates a hospital received victims from the incident scene. Dif. indicated the amount of information difference between the ICS (+) and (-). AVG indicates average value. SD shows standard deviation. Values are shown based in the time intervals of 5-to-10, 10-to-15, and 15-to-20 minutes.

8. Discussions

Based on the scenario, two distinct information gaps occurred between the ICS (+) and (-) at the ICP/Fire Command Post. During the ICS (-) drills, it appeared that agencies were not able to readily share information or access information other agencies had gathered. A clear example of this arose when a simulated traffic jam occurred, hampering the movement of rescue apparatus. In one ICS (-) drill, the fire command asked the on-scene police officers to help clear the traffic. This was done by sending a messenger on foot to the location where the police commander was located. The time involved in having messengers move between the command posts slowed response times. Quantitatively, an estimated 1.34-bit information value gap was caused by this delay.

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In general, interoperable communications and a central incident command post shared by on scene participating agencies may have positively impacted the initial information values at the ICP in the early stage of the drill. The data points to the ICS (+) groups having had specific advantages in terms of information sharing early in the drills, supporting prompt decision making.

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Around the 8-minute mark of the drill the ICS (-) were challenged by an artificial cell-phone network failure in the area. This resulted in the fire command not being able to directly contact the receiving hospital. The fire command was subsequently forced to send a unit with a fire service radio to the receiving hospital to establish a new wireless network between the two nodes. Until the fire radio arrived, the hospital was not able to receive vital information about the in-coming patients or the results of triage. These gaps of information values increased from 4.45 to 6.57 bits respectively. An important learning from these drills is that if regular land-line and cell phone networks fail, an improvised alternative communication network must be established. However, this adds an additional burden on response efforts.

Overall, the results from the 8 drills indicate that the ICS (+) groups had higher information values across each of the drills, while the ICS (-), had lower. It is possible that the information variable used in the tests may not be the only factor supporting the ICS (+) groups in gaining higher scores. However, the use of emergency drills provides a repeatable method for additional testing and confirmation. Further, the Information Entropy equation provides a systematic way of visualizing and comparing the differences in information values in emergency response drills.

9. Conclusion

As mentioned earlier, many of the management problems encountered during past emergency events are still experienced to this day. Fundamental changes are needed in Japanese response models if this situation is to change.

The management problems identified in previous earthquakes in Japan have similarities to those identified following the severe forest fires that prompted the development of the ICS response model. ICS was developed to mitigate the operational problems that arise during
unplanned multi-agency events, addressing issues with coordination, communications, and interoperability. The authors believe that ICS response model would contribute to the improvement of Japan's emergency response operations, particularly when multi-agency coordination is required. While the Japanese emergency response community seeks quantifiable evidence of the efficacy of new response models, this study has attempted to provide a first step towards developing evidence to support these practices.

The results of this research indicate that ICS users had higher information values than the non-users at the both the command post and the receiving hospital. To that end, the faster an Incident Commander can access accurate, validated, and current information, the faster he or she can make decisions and implement response actions.

This research was limited in scope to response drills engaging the Paramedic Course students simulating response agencies. However, the ICS response model showed increased values in supporting information sharing and collection when engaging with multiple represented agencies. Additional research may focus on other factors that may have improved, or negatively impacted, information values. Additionally, future research may examine the advantages of identifying a single commander working in an ICS response model on improving operations.

In advance of future research, response agencies may explore the use of a centralized incident command post during emergency response. This central location would allow leaders from each agency to gather physically, share information, and align strategies and goals. This could also serve as a step towards exploring shared response spaces without needing to begin examining command and control models.

Acknowledgement
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References
