Emergency Response Management (ERM) enables and supports emergency response operations across organizational, jurisdictional, and geographical boundaries. Recognizing the growing importance of ERM in countering both natural and manmade hazards, the US government ordered (vide Homeland Security Presidential Directive-5) the establishment, at the federal level, of a National Incident Management System (NIMS) [4]. The NIMS prescribes institutional response guidelines that help in establishing rule structures and developing a normative environment with defined tasks regarding what should be done during a response. Howitt and Leonard [6] point out that while NIMS does include a unified approach to incident management and incorporates standard command and management structures and aids coordination, it has the limitations in that NIMS is a technical system that can function effectively when its goals in a particular situation are consistent, clearly prioritized and coherent. Another limitation is that when situations present complex value conflicts or trade-offs NIMS lacks the ability to make politically legitimate decisions and to mobilize public support for subsequent action [6].
Effective coordination is an essential ingredient for ERM. The coordination of emergency response is demanding as it involves requirements typical of an emergency situation that include for example, high uncertainty and necessity for rapid decision making and response under temporal and resource constraints. Yet, the available literature on coordination issues relating to ERM consists largely of practitioner articles, governmental reports, and testimonies to congress. Academic research in this area, other than [2, 3, 8, 11], is scarce. Given the importance of ERM coordination, this area needs to be studied in greater detail. In this paper, we propose a framework to analyze coordination patterns in the emergency response arena, based primarily on semi-structured interviews with thirty-two emergency response personnel such as town, city, county, and state emergency managers and Federal Emergency Management Agency (FEMA) coordinators. We also illustrate the usefulness of the framework by applying it to an actual incident.

**Coordination in ERM**

The coordination of emergency response is challenging as it involves factoring in exigencies typical of an emergency situation such as great uncertainty; sudden and unexpected events; the risk of possible mass casualty; high time pressure and urgency; severe resource shortage; large scale impact and damage; and the disruption of infrastructure support necessary for co-ordination like electricity, telecommunication and transportation. This is complicated by factors such as infrastructure interdependencies, multi-authority and massive personal involvement, conflict of
interest, and the high demand for timely information. Table 1 elaborates some of these issues based on our conversations with emergency responders. (We also thank an anonymous referee for pointing out the challenges involved).

**Table 1: ERM Coordination at a Glance**

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Coordination Support Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>High uncertainty, sudden and unexpected events</td>
<td>- Real-time monitoring and timely alert notification for situation-awareness</td>
</tr>
<tr>
<td></td>
<td>- Improvisation and rapid adaptation of pre-defined plans to the scenario</td>
</tr>
<tr>
<td></td>
<td>- Periodical evaluation and update on existing coordination practices</td>
</tr>
<tr>
<td>Risk and possible mass casualty</td>
<td>- Threat, vulnerability and risk assessment and countermeasure</td>
</tr>
<tr>
<td></td>
<td>- Risk-sharing policy among parties involved</td>
</tr>
<tr>
<td></td>
<td>- Operational sustainability management</td>
</tr>
<tr>
<td>Increased time pressure and urgency</td>
<td>- Repository of related plans, procedures, policies</td>
</tr>
<tr>
<td></td>
<td>- Knowledge base and network of internal and external experts</td>
</tr>
<tr>
<td></td>
<td>- Efficient information and intelligence mining; knowledge elicitation</td>
</tr>
<tr>
<td></td>
<td>- Decision support technologies</td>
</tr>
<tr>
<td></td>
<td>- Psychological fortitude to deal with affect and behavior</td>
</tr>
<tr>
<td>Severe resource shortage</td>
<td>- Policies (e.g., priority list and access control) for resource use and requisition</td>
</tr>
<tr>
<td></td>
<td>- Logistic management and resource sharing network across local, national and international levels</td>
</tr>
<tr>
<td></td>
<td>- Self-equipped response teams</td>
</tr>
<tr>
<td></td>
<td>- Law and order, price control mechanism management</td>
</tr>
<tr>
<td>Large scale impact and damage</td>
<td>- Joint effort of governmental, public and private sectors across local, national and international boundaries</td>
</tr>
<tr>
<td></td>
<td>- Broad information, intelligence and resource sharing networks</td>
</tr>
<tr>
<td></td>
<td>- An integrated public communication network to inform, guide, and reassure the general public</td>
</tr>
<tr>
<td>Disruption of infrastructure support</td>
<td>- Protection of critical infrastructures</td>
</tr>
<tr>
<td></td>
<td>- Performance monitoring of built structures</td>
</tr>
<tr>
<td></td>
<td>- Planning for infrastructure interdependencies such as proximity of foliage and civil infrastructure</td>
</tr>
<tr>
<td></td>
<td>- Control of infrastructure redundancy</td>
</tr>
<tr>
<td></td>
<td>- Management of alternative infrastructures</td>
</tr>
<tr>
<td>Multi authority and massive people involvement</td>
<td>- Unified response command for coordination</td>
</tr>
<tr>
<td></td>
<td>- Establishment of role structures with corresponding authority, responsibility and accountability</td>
</tr>
<tr>
<td></td>
<td>- Management of power and regulation conflict</td>
</tr>
<tr>
<td></td>
<td>- Exercise of leadership and norms</td>
</tr>
<tr>
<td></td>
<td>- Communication operability and interoperability</td>
</tr>
<tr>
<td>Conflict of Interest</td>
<td>- Understand the political, ethnic, economic and environmental impact</td>
</tr>
<tr>
<td></td>
<td>- Shared vision and alignment of core interests</td>
</tr>
</tbody>
</table>
**Life Cycle Approach**

A life-cycle approach provides a broad and systematic view of the activities relating to emergency response management [12]. Therefore, the framework we suggest is adapted to each of the stages in the life cycle. The management of emergency response can be visualized in terms of three distinct sets of activities on the time line continuum [4]. These include actions taken (a) prior to an incident (typically deals with preparedness issues such as planning and training), (b) during the incident (mitigation), and (c) after the incident (a.k.a. the response and recovery stage). The cycle is completed when de-briefing has occurred and the lessons learnt are framed as actionable items designed to affect future preparedness. Many of the core elements of ERM coordination (such as activities, coordination objects and constraints) differ from stage to stage [12]. Cultural, political, regulatory and infrastructural (civil structures, people, process and technology) issues all cast an impact on coordination patterns and outcomes. In Figure-1 we present the schema of the framework developed by us, which represents not only a development of the work presented by Raghu et al. [9] but also a context modification of that work. The framework considers five basic elements that are applied to each stage of the life cycle:

- Task flow: tasks and interdependent relationships
◆ Resource: resource utilization management and dependencies
◆ Information: task-critical information collection, analysis, and distribution
◆ Decision: decision roles, rules, and structures
◆ Responder: relationships, team-think, group dynamics (such as culture), organizational dynamics, etc

**Figure 1: Emergency Response Coordination Life Cycle**

This framework conceptualizes the “during-incident” response stage as comprising of two distinct coordination patterns: (a) On-site response coordination (Mini-Second Cycle) and (b) Remote response coordination (Many-Second Cycle).

**Coordination Lifecycle**

In this section, we discuss coordination patterns along the entire coordination life cycle, based on our proposed framework.

**Coordination in pre-Incident Response**

Pre-event coordination establishes the level of operational capacity and overall readiness for resilience during emergency response. A typical disaster includes several
invariants, defined as those factors that remain unaffected by the changing conditions of the emergency, such as: creating emergency shelters in appropriate places; establishing a process for dealing with surge in hospital admissions; for working with degraded capacities; for maintaining law and order; for arranging evacuation across geographic boundaries, etc. These issues are addressed during coordinated planning and training exercises involving the stakeholders and results in the development of Standard Operating Procedures (SOP). “Planning” also addresses issues such as setting up contractual agreements with business entities for providing supplies during incident and creating infrastructure to deal with first and second responder issues (including affect and behavior). During major emergencies, the limits of local capability are soon reached and multiple agencies are involved in supporting additional response efforts. This typically requires both spatial and temporal coordination with organizations and personnel who follow different norms and practices. Training and exercise help in establishing necessary understanding between different players (whether from the same agency or from different ones) and conduces to smoother interaction between then during an actual incident. Setting up such training activities and table–top exercises also requires coordination. Therefore, coordination is a key issue in pre-incident activities. Table 2 includes the application of the framework to pre-incident activities.

**Coordination during Incident Response**
Coordination during an incident impacts both short-term and long-term outcomes. A plan-based approach to emergency response relies heavily on pre-incident preparedness and this sometimes leads to response inflexibility in the face of unexpected events. Variants in a disaster originate from hazard uncertainty; uncertainty as to the course of incident development; informational uncertainty; task flow uncertainty (whether sequential, consequential or cascading); organizational structure uncertainty; and environmental uncertainty. Uncertainties are managed by improvisations, prioritization and dynamic sourcing of capacities from other communities and external agencies, such as neighboring counties, state and federal agencies [5]. The variant or situation-dependent layers of knowledge create a context from which one can then understand the Incident Commander’s Intent. These layers may indeed serve as temporal agents during mitigation.

To support fast response during complex incidents, responders have to make rapid coordination decisions, which posit constraints on their capabilities to analyze coordination problems and explore the solution domain. Response to disasters can be viewed as consisting of an onsite response coordinating entity and a remote management entity such as EOC. Onsite response is usually reactive and the time-window for coordination is small. We characterize this as the “Mini-Second Coordination Cycle.” It is typically characterized by working with the local picture stemming from the local scenario. Without a proper understanding of the global picture, actions are motivated as a reaction to incidents from the immediate scene. Good coordination in civilian structures is better motivated by fostering common
understanding and this is accomplished by creating a common operating global view which lays out the commander’s intent and strategies. Efficient communication is an essential ingredient in the development and spread of common understanding and buy-in. A supervisory structure such as EOC deals with more strategic issues and works with a global picture, leveraging external resources to help on-site response. The actions of the EOC emanate based on a more reflective and proactive posture and the EOC commanders typically operate with a large time-window. We have therefore classified such coordination efforts as “Many-Second Coordination Cycle.” This concept (see Figure 2) is an adaptation from the work by Lewandowski et al.[7] in the area of survivable autonomic response architecture as part of a DARPA project. The concepts of mini-second and many-second coordination cycle relate to distinct coordination tasks (operation- vs. managerial-level), constraints (small vs. large time window; information/intelligence; and capability), and outcome quality (poor vs. good). Mini-second coordination addresses immediate response coordination needs while many-second coordination oversees and supports the former, for instance with resources and information.

![Figure 2: Mini-second and many-second coordination cycles](image-url)
This division of coordination tasks and responsibility allows better matches between coordinator expertise and task requirements [10]. Frontline response teams are trained to excel on domain-specific tasks (like firefighting and rescue) and the coordination of these tasks, while remote commanders focus on global issues such as inter-agency coordination, overall logistics and regulation compliance.

**Coordination in Post-Incident Response**

Effective and quick response and recovery is vital to the economic health of the affected region and also to the mental health of the citizenry. Recovery focuses on the return to normalcy of the impacted region and people. It is also a phase for debriefing and pondering over the details of the response effected, to learn from the incident so as to positively impact the building of resiliency to deal with future incidents better. It is also a time to replenish the consumable supplies and to return the response capacity back to readiness against new incidents in the future. Unless properly coordinated, the recovery may introduce new “disasters” for the incident victims and tangibly impact the budget.

**Framework**

In Table-2, we present a framework to analyze the coordination effort for managing response to an emergency. We apply the framework to all the three phases of the emergency life cycle.
Table 2: Emergency Coordination

<table>
<thead>
<tr>
<th>Pre-incident Phase</th>
<th>Coordination Issues</th>
<th>Coordination Goals</th>
<th>Coordination Mechanisms and Support</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task Flow</strong></td>
<td>Standard Operating Procedure development, planning for task flow dependencies, etc</td>
<td>Exact mapping from objectives to action-oriented checklist, task- sub task, goal decomposition for efficient implementation</td>
<td>Operation routine, task synchronization, task sequencing, training, exercise (table-top or drills)</td>
</tr>
<tr>
<td><strong>Resource</strong></td>
<td>Local and external resource management (e.g. critical infrastructure utilization in neighboring counties, contra-flow of traffic, public hospital utilization), request schemes, etc</td>
<td>Prioritizing, resource readiness management, establishment of acquisition mechanisms for external resource</td>
<td>Resource deployment and usage priority schemes, guidelines, resource standardization, mutual aid, donor assistance, inventorying</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>Risk assessment (e.g., chemical plants close to nursing homes), information on performance of civil infrastructures, information exchange, communication connectivity, risk assessment for engineered and built infrastructure, obtain information on tightly-coupled infrastructure interdependencies, etc</td>
<td>Integrated and inter-operable communication for agencies and communities, standardized communication instructions and report formats</td>
<td>Communication protocols, data vocabulary and message standards, communication operational guidelines, public alert systems</td>
</tr>
<tr>
<td><strong>Decision</strong></td>
<td>Decision structure development</td>
<td>Establishment of clear decision roles, compatible decision rules</td>
<td>Guidelines, protocols, knowledge sharing, community of practice (COP) structuring</td>
</tr>
<tr>
<td><strong>Responder</strong></td>
<td>Developing an organizational structure among relevant responder groups to create a scalable organization maintaining span of control, etc.</td>
<td>Clear individual authority, responsibility and accountability; ensure that responders know and understand their role within the Unified Incident Command System (ICS) structure (also ensure there will be no turf disputes among responders)</td>
<td>Guidelines, protocols, team meetings, mutual adjustment mechanism (e.g., liaisons), training with the ICS structure, - build familiarity and working relationships with local, state and federal partners, building structure to address mental welfare of first and second responders such as social organizations, etc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>During Incident Phase</th>
<th>Coordination Issues</th>
<th>Coordination Goals</th>
<th>Coordination Mechanisms and Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINI-Second Coordination Cycle</td>
<td><strong>Task Flow</strong> Detailed task assignment, task scheduling, etc.</td>
<td>Fit between task requirement and personnel expertise; smooth functioning of task flow; no conflicts, overlap, or duplication of efforts</td>
<td>Routines, schedules, synchronization, notification, sequencing, tracking</td>
</tr>
<tr>
<td><strong>Resource</strong></td>
<td>Resources utilization, reallocation, tactical use, etc</td>
<td>Efficient resource sharing among personnel, efficient resource positioning and utilization</td>
<td>Priority order (need based)</td>
</tr>
<tr>
<td>(Reactive)</td>
<td>Information</td>
<td>Direct information exchange between responders as well as with EOC</td>
<td>Good communications between responder groups; timely information flow</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Decision</td>
<td>Decision-making speed for rapid intervention and prevention</td>
<td>Efficient decision-making in terms of time and loss of life and property; ensure proper rest and mental stability of first responders</td>
<td>Decision role delegation, reliance on protocol, support for decentralized decision making, provide training, make mental health practitioners available to first responders on site if possible to avoid PTSD</td>
</tr>
<tr>
<td>Responder</td>
<td>Responder relationship, group dynamics, TeamThink.</td>
<td>High team spirit, ensuring trusting relationships in the completion of tasks</td>
<td>Coordinated pre-incident exercise, open interpersonal communication</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MANY - Second Coordination Cycle (Proactive, More Reflective)</th>
<th>Task Flow</th>
<th>Design and management of entire response activity, addressing task flow dependencies at macro-level, addressing scheduling of external activities, etc</th>
<th>Achievement of overarching response objectives; integration of local and external activities (State, Federal, NPO, private, public agencies)</th>
<th>Goal selection, task decomposition, plug-and-play teaming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource</td>
<td>Local and external resource utilization, staging of logistics, etc</td>
<td>Efficient acquisition of external resource and optimized allocation of available resource</td>
<td>Plan of mutual aid, donor assistance, resource typing, inventorying, requesting, procuring, tracking, priority, and reallocation</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>Global information utilization</td>
<td>Integrated and improved information, global operational picture, complete situational awareness</td>
<td>Multi-source information acquisition, centralized information analysis, secure “publish / subscribe tools” and public collaborative sharing for information collection and distribution based on social networking (e.g., MS Groove)</td>
<td></td>
</tr>
<tr>
<td>Decision</td>
<td>Decision making quality</td>
<td>Ensuring proper decisions dependent on global picture and strategic needs, changing decisions based on developing needs</td>
<td>Knowledge sharing, protocol breaking, joint-sense making, epistemic contestation, COP structuring</td>
<td></td>
</tr>
<tr>
<td>Responder</td>
<td>Multi-agency conflicts arising out of cultural differences, responder welfare issues, management of liaison with media, politically sensitive issues, providing clarity on legal matters, etc</td>
<td>Compatible goals, policies, interest, address jurisdictional policy difference (e.g., cross-border issues to deal with the sick, and infected); quarantine extensions in neighboring counties in case of a pandemic disaster, regional resource coordination to deal with surge in public health systems, etc</td>
<td>Team meetings, mutual adjustment, cross-boundary intervention, risk sharing, resolve turf disputes among responders if any.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recovery Phase</th>
<th>Coordination Issues</th>
<th>Coordination Goals</th>
<th>Coordination Mechanisms and Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Flow</td>
<td>Response and recovery planning to return region to normalcy as soon</td>
<td>Achievement of overarching recovery objectives, integration of local and external</td>
<td>Goal selection, task decomposition, plug-and-play teaming, operation routine, task synchronization, task sequencing</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Activities</td>
<td>Notes</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Resource</strong></td>
<td>Local and external resource management</td>
<td>Efficient acquisition and distribution of resources, fast demobilization, quick maintenance</td>
<td>Resource deployment priority, guidelines, resource standardization, mutual aid, donor assistance, replenishment</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>Publication of information that has been collected about recovery, information on pricing for award of contract for post-disaster activities</td>
<td>Consistent information content, timely distribution of public information and education to reduce public fear and build confidence, building community spirit, etc</td>
<td>Centralized information publishing, joint network of public and private media</td>
</tr>
<tr>
<td><strong>Decision</strong></td>
<td>Address contracts for debris clean-up, aid decision making with county officials to arrive at consensus about financial costs relating to recovery, etc</td>
<td>Strategic decision (short- and long-term) in terms of outcome; restoration of normalcy; removing constraints such as residency and driving bans, etc</td>
<td>Priority, guidelines, protocols, knowledge sharing</td>
</tr>
<tr>
<td><strong>Responder</strong></td>
<td>Agency debriefing and evaluation, addressing long term issues of both first and second responders</td>
<td>Free discussion, healthy relationship</td>
<td>Facilitator, boundary-spanner, guidelines, protocols, team meetings, mutual adjustment</td>
</tr>
</tbody>
</table>


**Application of Framework**

In this section, we demonstrate the application of the coordination framework presented in the previous section to the “during incident” management of a real incident.

At 3:07 pm on Wednesday, July 18, 2001, a CSX Transportation train derailed in the Howard Street Tunnel under the streets of downtown Baltimore, Maryland (http://www.usfa.dhs.gov/downloads/pdf/publications/tr-140-508.pdf). The train was carrying a variety of freight and hazardous materials, with three locomotives pulling 60 cars. Complicating the scenario was the subsequent rupture of a 40-inch water main that ran directly above the tunnel. The flooding hampered extinguishing efforts, caused several city streets to collapse, knocked out electricity to about 1,200 customers and flooded nearby buildings. The derailment also interrupted a major line associated with the Internet and an MCI fiber optic telephone cable.

During the two-day response, five alarms were requested with seventeen engines, eight trucks and three battalions, in addition to the HazMat, EMS, and Rescue teams. One hundred and fifty firefighters were on the scene, working to extinguish the fire. The fire extinguishing operations were performed from both ends of the tunnel as well as through manholes located at Howard and Lombard streets. The city of Baltimore activated the civil defense sirens at 5:45 pm to warn citizens of impending danger from the fire and hazardous materials. On the night of the derailment, city officials closed down entrances to the city from all major highways and cancelled major public events.
NIMS suggests that the Incident Command Post (ICP) perform an EOC-like function in small-scale incidents (pg 26) [4]. In this response, the on-site management teams assumed the overall management support and supervision role (the many-second coordination cycle) and the individual divisions (such as Camden, Mt. Royal, and Tower sectors) responded at the operational level (the mini-second coordination cycle). Table-3 shows the application of our framework to this real incident.
Table 3: Application of Framework to CSX Train Derailment and Tunnel Fire Incident, Baltimore, Maryland, 2001

<table>
<thead>
<tr>
<th>During-Incident Phase</th>
<th>Example Coordination Issues</th>
<th>Example Coordination Goals</th>
<th>Example Coordination Mechanisms and Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINI-Second Coordination Cycle</td>
<td>Task Flow</td>
<td>Interior fire attack operations on the fire in the tunnel, support operations dealing with water supply, security, medical services, etc</td>
<td>Task division and scheduling such as - Interior attack teams laid hose lines and entered the hazard area to find and extinguish the fire - During the interior attacks, the “second in” engines functioned as water supply to support interior attacks - The police secured and blocked the surrounding area and ensured that only the response resources went through - While the 5” diameter hose was lowered into the tunnel through the manhole, firefighters entered the tunnel and attached their hose lines to the 5” water supply and started firefighting - Individual cars from the end of the train were removed to enable firefighters to attack the fires in the other cars</td>
</tr>
<tr>
<td>Resource</td>
<td>Resources utilization of personnel, heavy and light rescue equipment, water supply, and communication frequency from Baltimore City Fire Department, City Police Department, City Emergency Management, Baltimore County Fire Department</td>
<td>Efficient and effective use of resources - Allocation of a specific radio frequency for ground operations, maintenance, and management functions - Allocation of water resource, supplied through a 5” water supply manifold through a manhole among interior attack teams - Efficient use (distribution and refill) of personal protective equipment such as Self Contained Breathing Apparatus (SCBA) among firefighter shifts who entered the tunnel - Efficient use of rehabilitation services, provided by EMS, for the firefighters - Allocation of crews (engines, trucks, and battalions) among the Camden sector (north end), Mt. Royal sector (south end), and Tower sector</td>
<td>Resources were deployed as per predetermined plans, and priority-based cause-effect analysis</td>
</tr>
<tr>
<td>Information</td>
<td>Communication between the IC, the fire attack teams and the supportive teams (such as police, EMS, and Haz-Mat)</td>
<td>Real-time information exchange among the interior attack teams for safety awareness and assistance, fast information sharing between the interior attack teams and incident commander for situation report</td>
<td>Baltimore Fire Department 800 MHz radio systems, hand signals, narratives</td>
</tr>
</tbody>
</table>

1 We would like to thank Mr. James Guy (Ex-Fire Chief and now Chief of Environmental Affairs, University at Buffalo) and Dave Humbert (Fire Chief – North Bailey, Amherst, New York) for their insight into the Baltimore train derailment incident
| Decision | Decision making for ground operations such as immediate fire suppression and containment | Effective interpretation of operational challenges (sizing up the situation and making resource assessment) to develop rapid intervention schemes with appropriate level of personal and operational safety | Incident priorities (life safety, property conservation and extinguishment), Standard Operation Procedures (SOP), Haz-Mat precautions (flame and chemical contact protection, supplied air respiration, the hazards of Boiling Liquid Expanding Vapor Explosion), building safety guidance (in the face of weakening structural integrity of the tunnel and immediate surrounding areas) |

| Responder | Responders and helpers learn to work together | Confident and trustful relationships among the responders and among the helpers, clear accountability, accurate expectations of team members’ actions and capabilities | The opportunity of response partners to exercise together in pre-incident training and drills, to instill personal and team confidence |

| MANY-Second Coordinat ion Cycle | Task Flow | Supervise and support the on-going tunnel firefighting and public welfare | Timely and necessary operation interventions to ensure the personal safety (responders and the public) and task progress of the entire response effort - Appropriate interruptions of the attack on the fire to avoid both exposure to risks and wastage of resource - During the response, the U.S. Coast Guard deployed a series of floating booms to protect the Inner Harbor against contamination and potential hazardous runoff from the derailment site - While fire was on, citizens of Mount Royal Station were offered the choice to leave for the “shelter-in-place” | Goal selection, task decomposition, plug-and-play teaming, coordination by expertise |

<p>| Resource | Management of additional response resources from the City of Baltimore Department of Public Works (DPW); from the Representatives of the South Baltimore Industrial Mutual Aid Plan, CSX Transportation, the Maryland Department of Environment; the National Transportation Safety Board and the U.S. Coast Guard | Efficient acquisition of additional resources - Apply mutual aid resources to support fire scene operations and stand-by services in event of additional alarm calls - Allocating and maintaining the resource staging area for rapid distribution and demobilization of resources | Need-based request (multiple alarm calls), plan of mutual aid |</p>
<table>
<thead>
<tr>
<th>Information</th>
<th>Efficient management of task-critical information among stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- The on-site command team kept in close contact with the CSX Transportation companies for train- and cargo-related information</td>
</tr>
<tr>
<td></td>
<td>- Hazard analyses of smoke, air and water were quickly delivered to the on-site command team from the Maryland Department of Environment (MDE), U.S. Environment Protection Agency (EPA), U.S. Coast Guard, and CSX contractor continually during the response process</td>
</tr>
<tr>
<td></td>
<td>- Public announcements (including civil defense sirens) were made over radio and television to alert citizens and to initiate a &quot;self-in-place&quot; advisory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision</th>
<th>Effective evaluation of the response situation and timely transitions of overall response strategies for higher effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- From initial aggressive attacks (initial direct attacks through both ends of the tunnel) to passive attack (waiting for the fire to burn out) to defensive attack (by taking advantage of the rupture of the water main) to aggressive attack (attack through manhole on the street)</td>
</tr>
<tr>
<td></td>
<td>- With the reported water main rupture on the street right above the tunnel, the on-site management team negotiated with the Baltimore DPW to keep the water flowing from the ruptured water main into the tunnel for two hours. This decision effectively cooled the tunnel and prevented a Boiling Liquid Expanding Vapor Explosion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Responder</th>
<th>Management of relationship with the external agencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The on-site management team placed confident on the information provided by the MDE, Coast Guard, CSX contractor, EPA while issuing orders to the interior fire teams. The onsite management team and the city management trusted each other to utilize the water breakout for firefighting at the cost of massive impact on the city’s water supply and risk of necessitating reconfigurations of the city water systems</td>
</tr>
</tbody>
</table>

|  | Computer Aided Dispatch (CAD) system, Baltimore City Communication Center, Dispatch service, public and private networks |
|  | Protocol breaking, join-decision making, cost-benefit analysis |
|  | Working experience with related agencies through training; develop strong partnership with agencies responsible for responding to incidents; institute pre-defined plans |
Conclusion

Coordination in the context of emergency response is an understudied research issue. It is an important problem, as it impacts life and property in the affected area. We have proposed a framework to analyze coordination patterns along the emergency response lifecycle. This framework may be further utilized by researchers and practitioners to (1) depict emergency coordination practices along focal dimensions elaborated in the framework, (2) understand the overarching requirements for coordination design and implementation, and (3) identify coordination ineffectiveness and analyze the alternatives for optimal solutions. This paper has also applied the framework to a real-life emergency incident as a proof of concept of its relevance and usability. The case application demonstrates not only the applicability of the framework during disasters but also serves as a reminder template of the number of things to consider while countering emergencies and disasters.

It is important to point out that a number of new technologies have emerged in recent years to enable better emergency response coordination. Example solutions include wireless mesh networks (e.g., CalMesh - calmesh.calit2.net), sensor networks (e.g., ASPECT – www.epa.gov/naturalevents/flyinglab.htm), knowledge management systems (e.g., RKBP - www.rkb.mipt.org), geographic information systems (e.g., CATS - cats.saic.com), communication standards (e.g., CAP - www.incident.com/cap), incident forecast and analysis programs (e.g., SLOSH - www.fema.gov/plan/prevent/nhp/slosh_link.shtm), peer-to-peer communication platforms (e.g., Microsoft Groove- www.groove.net), collaborative work systems (e.g.,
E-Team – www.eteam.com), and command and control systems (e.g., DisasterLAN -www.disasterlan.com). These technology pieces address parts of the puzzle and have to be leveraged to improve coordination. However, the discussion of these technologies in the context of emergency response management and coordination systems is beyond the scope of the current paper and will be taken up in future research.

Acknowledgement

This research has been funded by NSF under grant 0705292. The usual disclaimer applies. Our thanks also go to the many emergency response coordinators from FEMA and State of New York (especially Western New York) for their valuable insights (For details please see: http://ack.ifastnet.com/ack.html).

References

Survivability Conference and Exposition (DISCEX II’01) (2001).


