finding was that crews responding with a BLS engine and an ambulance with two ALS providers completed the tasks that follow cardiac arrest 50 seconds *sooner* than crews with an ALS provider on both the engine and ambulance. As noted, this counter-intuitive difference in the results may be attributable to the delay of the patient arrest time based on the arrival of the 12-Lead ECG monitor with the two-person ALS Ambulance crew. The 12-Lead ECG task *end time* was the arrest *start time*. In this scenario, there were instantaneously two ALS providers present at the arrest rather than the one ALS provider placing the 12-Lead ECG device in the ALS engine /ALS Ambulance crew.

A review of the patterns of significant findings across task start times showed mixed results. An ALS on an engine showed an advantage (sooner task starting times) over an ALS on an ambulance for a few tasks located earlier in the cardiac response sequence (specifically, ALS Vitals 12-Lead through IV access). A first responder with four-person crew also showed shorter start times for a few early tasks in the cardiac response sequence (initial airway, breathing and circulation (ABCs), and the ALS Vitals 12-Lead and expose chest sequence). More importantly, a sequential time advantage appears for the last three tasks of the sequence (analyze shock #2 through package patient).

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 45 seconds faster than crews with a BLS engine and two ALS providers on the ambulance. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks from the 'at patient time' to completion of packaging 70 seconds faster than first responder crews with three persons, and 2 minutes and 40 seconds faster than first responder crews with two persons. Additionally, *after the patient arrested*, an assessment of time to complete remaining tasks revealed that first responders with four-person crews completed all required tasks 50 seconds faster than three-person crews and 1.4 minutes (1 minute 25 seconds) faster than two-person crews.

Summary

While resource deployment is addressed in the context of three basic scenarios, it is recognized that public policy decisions regarding the cost-benefit of specific deployment decisions are a function of many factors including geography, resource availability, community expectations as well as population demographics that drive EMS call volume. While this report contributes significant knowledge to community and fire service leaders in regard to effective resource deployment for local EMS systems, other factors contributing to policy decisions are not addressed. The results, however, do establish a technical basis for the effectiveness of first responder crews and ALS configuration with at least one ALS level provider on first responder crews. The results also provide valid measures of total crew size efficiency in completing on-scene tasks some of which involve heavy lifting and tasks that require multiple responders to complete.

These experimental findings suggest that ALS provider placement and crew size can have an impact on some task start times in trauma and cardiac scenarios, especially in the latter tasks leading to patient packaging. To the extent that creating time efficiency is important for patient outcomes, including an ALS trained provider on an engine and using engine crew sizes of four are worth considering. The same holds for responder safety – for access and removal and other tasks in the response sequence, the availability of additional hands can serve to reduce the risks of lifting injuries or injuries that result from fatigue (e.g., avoid having small crews repeatedly having to ascend and descend stairs).

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FIRE FIGHTER SAFETY AND DEPLOYMENT STUDY

Report on EMS Field Experiments

Increasing demands on the fire service, including the rising number of EMS responses, point to the need for scientifically-based studies on the effect of first responder crew size, Advanced Life Support configuration, and the number of Advanced Life Support (ALS) personnel on scene on the safety of responders, as well as the operational efficiency and effectiveness of fire departments responding to emergency medical incidents. To address this need, a research partnership of the Commission on Fire Accreditation International (CFAI), International Association of Fire Chiefs (IAFC), International Association of Fire Fighters (IAFF), National Institute of Standards and Technology (NIST), and Worcester Polytechnic Institute (WPI) was formed to conduct a multiphase study of firefighter safety and the deployment of resources. A portion of that study, as reported here, includes an assessment of time-to-tasks for EMS incidents.

Beginning in FY 2005, funding was provided through the Department of Homeland Security (DHS)/ Federal Emergency Management Agency (FEMA) Grant Program Directorate for Assistance to Firefighters Grant Program-Fire Prevention and Safety Grants. In addition to the EMS field experiments described in this report, the multiple phases of the overall research effort include development of a conceptual model for community risk assessment and deployment of resources, implementation of a generalizable department incident survey, and delivery of a software tool to quantify the effects of deployment decisions on resultant firefighter and civilian injuries and on property losses.

The first phase of the project was an extensive survey of more than 400 career and combination (both career and volunteer) fire departments in the United States with the objective of optimizing a fire service leader's capability to deploy resources to prevent or mitigate adverse events that occur in risk- and hazard-filled environments. The results of this survey are not documented in this report, which is limited to the EMS experimental phase. The survey results will constitute significant input into the development of a future software tool to quantify the effects of community risks and associated deployment decisions on resultant firefighter and civilian illnesses and injuries.

The National Fire Protection Association estimates that 10,380 EMS workers were exposed to infectious diseases in 2008 (Karter, 2009). Another study noted that almost 10 % of Emergency Medical Technicians (EMTs) and Paramedics miss work at any given time due to job-related illness or injury (Studnek et al, 2007). Another study noted that injury rates for EMS workers are higher than rates reported by the Department of Labor (DOL) for any other industry in 2000 (Maguire et al, 2005) and another study noted that EMS providers have a high risk for occupational injury, with approximately 25 % of workers reporting at least one work-related injury in the previous six months. Many of these injuries were the result of falls or lifting patients (Heick, 2009). Funding and additional research are critical to further defining the high risks to firefighters during EMS responses and developing interventions to mitigate this serious problem.

In order to address the primary research questions using realistic scenarios, the research was divided into three distinct, yet interconnected parts.

- Part 1 — Time-to-task experiments related to gaining access to a patient and removing the patient from the incident scene.
- Part 2 — Time-to-task experiments related to the care of a victim with multi-system trauma.
- Part 3 — Time-to-task experiments related to the care of a victim with chest pain and witnessed cardiac arrest.

These parts included the most basic elements of an overall EMS response, which are — access the patient, conduct patient assessment, deliver on scene patient care, package the patient, and remove the patient from the scene to a transport-capable vehicle.

Scope

The EMS portion of the Firefighter Safety and Deployment of Resources Study was designed solely to assess the personnel number and configuration aspect of an EMS incident for responder safety, effectiveness, and efficiency. This study does not address the efficacy of any patient care intervention. This study does however quantify first responder crew size, i.e., the number and placement of ALS trained personnel resources on the time-to-task measures for EMS interventions. Upon recommendation of technical experts, the investigators selected trauma and cardiac scenarios to be used in the experiments as these events are resource intensive and will likely reveal relevant differences in regard to the research questions. The applicability of the conclusions from this report to a large-scale hazardous or multiple-casualty event has not been assessed and should not be extrapolated from this report.

EMS protocols pertaining to the treatment and transport of patients vary by departments. For the purpose of this study, apparatus arrival times and on scene tasks were standardized by technical experts. Individual performance times were recorded for each task. Response data from more than 300 United States Fire Departments show that when dispatched simultaneously, a first responder arrives prior to an ambulance in approximately 80 % of EMS responses, (IAFC/IAFF, 2005). Therefore, arrival times of the first responder engine and the ambulance were staggered. Additionally, in real-world situations, as in this study, many of the tasks can be performed simultaneously based on the number and training level of responding personnel. Attempts to generalize the results from these experiments to individual departments must take into account response and patient care protocols and equipment that may vary from those used in the experiments.

Primary Findings

The objective of the experiments was to determine how first responder crew size, ALS provider placement, and the number of ALS providers is associated with the effectiveness of EMS providers. EMS crew effectiveness was measured by task intervention times in three scenarios including patient access and removal, trauma, and cardiac arrest. The results were evaluated from the perspective of firefighter and paramedic safety and scene efficiency rather than as a series of distinct tasks. More than 100 full-scale EMS experiments were conducted for this study.

Hundreds of firefighters and paramedics are injured annually on EMS responses. Most injuries occur during tasks that require *lifting or abnormal movement* by rescuers. Such tasks include lifting heavy objects (including human bodies both conscious and unconscious), manipulating injured body parts and carrying heavy equipment. Several tasks included in the experiments fall into this category, including splinting extremities, spinal immobilization (back boarding) and patient packaging. Similar to the lifting or heavy workload tasks, larger crews were able to complete the labor intensive tasks using multiple crew members on a single task to assure safe procedures were used reducing the likelihood of injury or exposure.

A number of tasks are also *labor intensive*. These tasks can be completed more efficiently when handled by multiple responders. Several tasks in the experiments are in this category. These include checking vital signs, splinting extremities, intubation with spinal restriction, establishing I.V. access, spinal immobilization, and patient packaging. During the experiments larger crews completed these tasks more efficiently by distributing the work load among more people thereby reducing the likelihood of injury.

Finally, there are opportunities on an EMS scene to reduce scene time by completing tasks simultaneously rather than sequentially thus increasing operational efficiency. For the experiments, crews were required to complete all tasks in each scenario regardless of their crew size or configuration. Therefore, patterns in task start times and overall scene times reveal operational efficiencies. When enough hands are available at the scene to complete tasks simultaneously, this leads to overall time reductions relative to smaller crews that are forced to complete tasks sequentially.

Patient Access and Removal

With regard to accessing the patient, crews with three or four first responders reached the patient around half a minute faster than smaller crews with two first responders. With regard to completing patient removal, larger first responder crews in conjunction with a two-person ambulance were more time efficient. The removal tasks require heavy lifting and are labor intensive. The tasks also involve descending stairs while carrying a patient, carrying all equipment down stairs, and getting patient and equipment out multiple doors, onto a stretcher and into an ambulance.

The patient removal results show substantial differences associated with crew size. Crews with three- or four-person first responders complete removal between 1.2 – 1.5 minutes faster than smaller crews with two first responders. All crews with first responders complete removal substantially faster (by 2.6 - 4.1 minutes) than the ambulance-only crew.

These results suggest that time efficiency in access and removal can be achieved by deploying three- or four-person crews on the first responding engine (relative to a first responder crew of two). To the extent that each second counts in an EMS response, these staffing features deserve consideration. Though these results establish a technical basis for the effectiveness of first responder crews and specific ALS crew configurations, other factors contributing to policy decisions are not addressed.

Trauma

Overall, field experiments reveal that four-person first responder crews completed a trauma response faster than smaller crews. Towards the latter part of the task response sequence, four-person crews start tasks significantly sooner than smaller crews of two or three persons.

Additionally, crews with one ALS provider on the engine and one on the ambulance completed all tasks faster and started later tasks sooner than crews with two ALS providers on the ambulance. This suggests that getting ALS personnel to the site sooner matters.

A review of the patterns of significant results for task start times reinforced these findings and suggests that (in general) small non-significant reductions in task timings accrue through the task sequence to produce significantly shorter start times for the last third of the trauma tasks.

Finally, when assessing crews for their ability to increase on-scene operational efficiency by completing tasks simultaneously, crews with an ALS provider on the engine and one ALS provider on the ambulance completed all required tasks 2.3 minutes (2 minutes 15 seconds) faster than crews with a BLS engine and two ALS providers on the ambulance. Additionally, first responders with four-person first responder crews completed all required tasks 1.7 minutes (1 minute 45 seconds) faster than three-person crews and 3.4 minutes (3 minutes and 25 seconds) faster than two-person crews.

Cardiac

The overall results for cardiac echo those of trauma. Regardless of ALS configuration, crews responding with four first responders completed all cardiac tasks (from at-patient to packaging) more quickly than smaller first responder crew sizes. Moreover, in the critical period following cardiac arrest, crews responding with four first responders also completed all tasks more quickly than smaller crew sizes. As noted in the trauma scenario, crew size matters in the cardiac response.

Considering ALS placement, crews responding with one ALS provider on both the engine and ambulance completed all scene tasks (from at-patient to packaging) more quickly than a crew with a BLS engine and two ALS providers on the ambulance. This suggests that ALS placement can make a difference in response efficiency. One curious