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LEAN FIRE MANAGEMENT: A FOCUSED ANALYSIS OF THE INCIDENT COMMAND SYSTEM BASED ON TOYOTA PRODUCTION SYSTEM PRINCIPLES

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in Mechanical Engineering in the
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By

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ABSTRACT

LEAN FIRE MANAGEMENT: A FOCUSED ANALYSIS OF THE INCIDENT COMMAND SYSTEM BASED ON TOYOTA PRODUCTION SYSTEM PRINCIPLES.

A primary role of the Incident Command System is to learn from past incidents, as illustrated by its origins in the wildland firefighting community. Successful emergency response operations under the Incident Command System has prompted its nationwide spread, this promulgation critically relies on the system's capability to stabilize and continuously improve various aspects of emergency response through effective organizational learning. The objective of this study is to evaluate the potential to apply fundamental principles of the Toyota Production System (Lean manufacturing) to improve learning effectiveness within the Incident Command System. An in-depth review of literature and training documents regarding both systems revealed common goals and functional similarities, including the importance of continuous improvement. While these similarities point to the validity of applying Lean principles to the Incident Command System, a focus on the systematic learning function of the Incident Command System culminated in the discovery of gaps in approaches proposed by the Incident Command System framework. As a result, recommendations are made for adjustments in systematic problem solving to adapt Lean principles of root cause analysis and emphasis on standardization of successful countermeasures to benefit the system. Future recommendations are also proposed based on the author's understanding of the system.

KEYWORDS: Incident Command System, Fire Management, Lean Manufacturing, Toyota Production System, Lean Systems Program

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12/10/14

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CHAPTER 1: INTRODUCTION

1.0 Purpose of Thesis

The goal of this thesis is to evaluate the potential to apply fundamental principles of Lean Manufacturing to facilitate continuous improvements for users of the Incident Command System (ICS). The Incident Command System is instrumental in driving the management of all incidents, large or small, including human and lightning caused wildfires in forests, grasslands, and preserved or monitored areas of the United States (hereinafter referred to as “wildland fires”). The term “Lean Manufacturing” indicates that operational methods based on Toyota Production System (TPS) principles are in place within some model area of, or throughout the entirety of, an organization.

Key references were used throughout this thesis in order to compare the Incident Command System with a successful Lean manufacturing management system as an effort to analyze possible gaps between the two. This approach revealed encouraging similarities while also illustrating differences between the two systems and justifications for why they are as such. This analysis and reasoning was formulated through an understanding of what each system intends to achieve through the work they do at the level closest to production of a product or service. Furthermore, the intent of this thesis was not to redefine the direct work done in the production of these products or services.

1.1 Introduction

Though beautiful in many regards, Mother Nature is capable of many awe-inspiring processes that can result in the destruction of property or loss of human life. The rage exhibited by an earthquake can tear apart homes, scarring the people involved, as well as leaving scars on the very earth itself. Similarly, hurricanes can approach quickly and devastate high density populations while spreading disruptive weather patterns throughout wide regions of surrounding areas. Those same severe storms blow across the land relentlessly, capable of producing deadly tornadoes or lightning that endanger the people in their paths.

Fire is another phenomenon that deserves to be added to this list. The inevitability of fire occurrence in our lives has prompted dedicated annual seasons where precautions are taken and emphasized publically in hopes of reducing the frequency and severity of incidents. Also, fire can occur post-incidentally from any one of these events, or can be started due to human influence. In some cases, fire can be beneficial to the local ecosystem [1], whereas in other cases fire is completely and totally unwanted. For either case, it is important that we understand fire in depth so our communities can be prepared when incidents occur.

1.2 United States Fire Statistics

The statistical estimates referenced in the following section are used to illustrate a very broad topic, the effects of fire in the United States. As such, it was important to gather a complete set of data published in 2011 in order to present a more wholistic view of the situation. The most current and comprehensive reports are produced by the National Fire Protection Association (NFPA), and the most recent nationwide cost estimate for overall fire impact was published in late 2014 using data concerning 2011. This 3 year gap is indicative of the time it takes to gather, process, and interpret all the data that factors into this complex estimate for these reports. However, the use of 2011 data here should present an important illustration of the impact that fire has had in the United States. Furthermore, these NFPA statistics were published with the same intent of providing a very high level depiction, and these numbers are said to have a broad uncertainty while giving a reasonable idea of the major role that fire plays in our economy [2].

The impact of fire on the United States is tremendous, and it reaches well beyond suppression costs and property damage. The National Fire Protection Association estimated total fire costs in the United States to be $329 billion in 2011, which was equivalent to 2.1% of the 2011 U.S. Gross Domestic Product (GDP) [2]. Figure 1 illustrates the estimated total costs for fire in the United States from the year 2000 through 2011 based on these NFPA statistics [2].

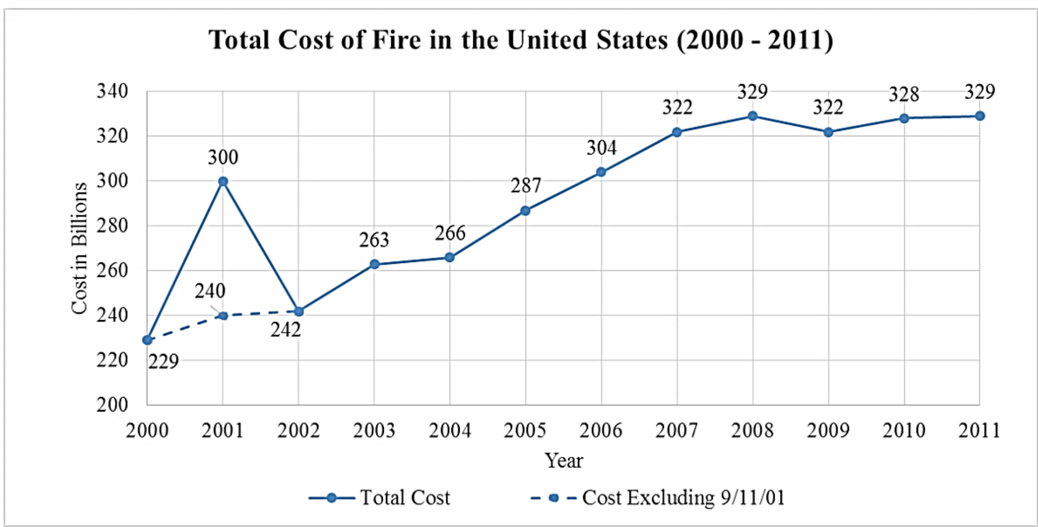


Figure 1: Estimated total cost of fire in the U.S. (2000-2011) [2].

When looking at these overall cost estimates, it's worth noting that the total cost of fire in 2011 was higher than that of 2001, when major catastrophic damage and losses were suffered on September 11, 2001. Figure 1 also shows the total cost for 2001 excluding the estimated costs related to the events of 9/11 to illustrate $60 billion of losses from incidents related. If this cost were incurred in 2011, with inflation taken into consideration, it's easy to see the total cost of fire reaching nearly $400 billion dollars in a single year. The contributing factors to the total cost of fire in 2011 were broken down in NFPA reports [2], and for clarity these categories are visualized in Figure 2.

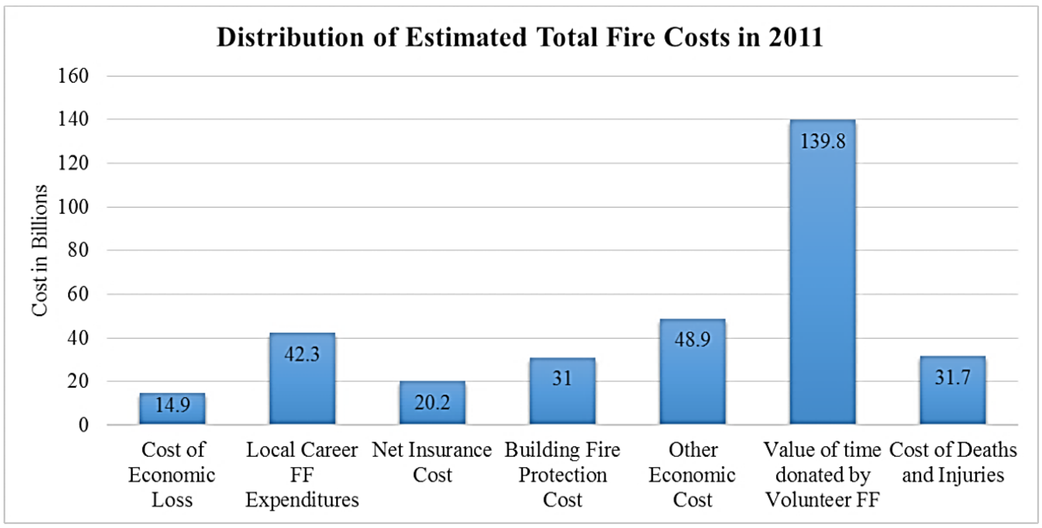


Figure 2: Breakdown of estimated total cost of fire in U.S. for 2011 [2].

The highest cost in the breakdown is attributed to volunteer firefighters, but this estimate illustrates savings based on the monetary value added by the volunteers providing their services for little to no compensation [2] [3]. It must also be noted that in the "Third Needs Assessment for the United States," published in 2011, the NFPA estimated 71% of the nation's fire departments in 2010 were classified as volunteer departments [4]. The second highest cost actually incurred by fire services according to this breakdown is the expenditures of local career fire departments. If the volunteer contributions are combined with the career contributions, this would give a total proposed firefighter expenditure of $182.1 billion in the United States. The estimated expenditures from the reports included calls answered with no incident, emergency medical services, as well as fire prevention, monitoring, mitigation, suppression, and other activities that must be undertaken in order to protect the public from incidents [2].

According to the NFPA estimate, these costs are a direct result of around 1.38 million fires that occurred in 2011, where 17,500 civilians and 70,090 firefighter injuries resulted [5] [6]. Furthermore, within these incidents, 3,005 civilians and 61 firefighters lost their lives [5] [6] [7]. A note in Karter's NFPA report regarding injuries and losses resulting from fire states that, "the term 'civilian' includes anyone other than a firefighter, and covers public service personnel such as police officers, civil defense staff, non-fire service medical personnel, and utility company employees" [5].

As a subset of these 1.38 million fires, the NFPA also estimated that 338,000 of these were fires related to "brush, grass, or wildland fires" [5]. Wildland fire statistics from the National Interagency Fire Coordination Center (NIFC), strictly regarding federal suppression and associated costs, indicated that 82,798 wildland fires occurred on private, state, and federal land in 2011, including 8,672 prescribed fires [8]. Figure 3 shows that the federal suppression costs for these fires from 2000 to 2011 varied between approximately one to two billion U.S. dollars for private, state, and federal land combined [8].

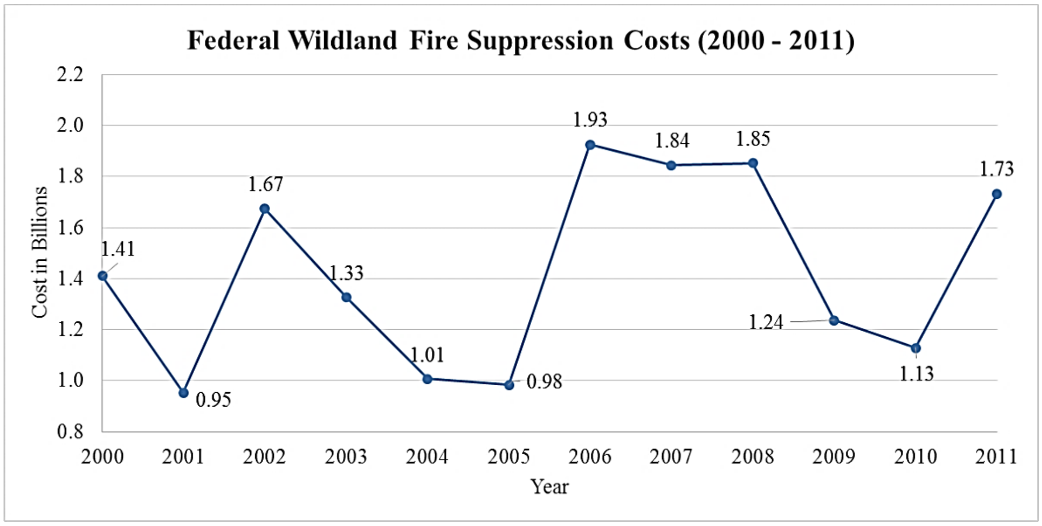


Figure 3: Federal Wildland Fire Suppression Costs (2000-2011) [8].

According to the figure, federal cost of wildland fire suppression for private, state, and federal land has shown variation between $1 billion and $2 billion from 2000 to 2011 [8]. This variation alludes to the lack of predictability from year to year in planning for the processes of wildland fire suppression. This is also reflective of the many factors that contribute to wildland fire management.

Federal wildland fire suppression costs in 2011 reached $1.73 billion for the suppression of the 82,798 fires considered [8]. The higher estimate of 338,000 brush, grass, and wildland fires from the NFPA could be estimated to have cost around $7 billion, if it’s assumed that all incidents were exactly the same in severity and scope. However, while this type of estimate may serve for a general perspective, it’s simply not realistic to assume that any two incidents are exactly the same. Some aspects of incident response will always vary with respect to resource requirements and availability, as well as management approach. However, the estimated costs of fire clearly indicate that better understanding of fire and the ability to better manage it are crucial going forward.

1.3 General Combustion Research

There have been great strides by researchers in trying to achieve a better understanding of physical fire based phenomena, and this research has resulted in fire being commonly utilized in today's society. Combustion research has progressed enough over the years to provide the internal combustion engine as well as sophisticated heating and cooling equipment. Designers, maintenance personnel, and operators of these devices have enough knowledge to safely control them, no matter that their power comes from spark based ignitions and explosion based power generation. This illustrates the knowledge and skill possessed by members of the research community to use experimentation, fundamental theory, and computational methods to better understand the thermodynamics, fluid dynamics, chemical kinetics, and transport mechanisms which promote fire occurrence and behavior [9].

The abnormal occurrence of fire in our world has been researched just as extensively. The justification is clearly associated with the costs associated as well as the number of fatalities and injuries resulting from these incidents.

1.4 Wildland Fire Research

A great deal of effort has been contributed to researching wildland fire behavior in an attempt to provide better understanding to the people who risk their own lives in order to save others. This research begins fundamentally with the causes of ignition and flame spread. Historically, radiative heat transfer had been accepted as the dominant trigger for wildland fire ignition and flame spread. Therefore, radiation based ignition has been studied extensively to better understand occurrences of wildland fire and develop models for predictive purposes [10]. However, fire has been observed and explored to discover a major role played by convective heat transfer, thus the exclusion of convection also excluded a large part of the mechanics behind ignition theory and flame propagation [9] [10]. These types of discoveries bring us ever closer to a solid definition of fire but there is still a long road ahead before we fully understand it.

Ultimately, the firefighting community must continue to push forward and respond to incidents as effectively and efficiently as possible. The drive for stable fire protection and mitigation, along with the need for methods capable of improvement to keep up with national trends, brings to light the importance of research into the overall fire management system itself. Fortunately, at the basic foundational level in which it was developed, the system strives to provide some clarity and stability to a fairly chaotic profession.

1.5 Fire Management in the United States

Both urban and wildland fire management are heavily influenced by documents and systems in place, which are intended to highlight the best method for approaching fire-based incidents. These documents also take into consideration various factors. A list of some well-known documents and systems can be seen in Figure 4. Each of these are intended to guide firefighters and help keep the firefighting community consistent through standard codes, regulations, and sharing of information.

1. Code of Federal Regulations (CFR)
2. Occupational Safety and Health Administration (OSHA)
3. National Fire Protection Association (NFPA)
4. National Incident Management System (NIMS)
5. Resource Management Plans (RMP)
6. Fire Management Plans (FMP)
7. Incident Command System (ICS)
8. Standard Operating Procedures (SOPs)

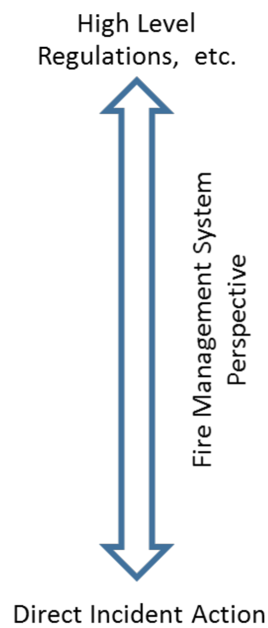


Figure 4: Partial list of guiding documents and systems in place for fire management.

Regulation or codification of standards may come from entities such as the National Fire Protection Association (NFPA), the Occupational Safety and Health Administration (OSHA), they may be published within the Code of Federal Regulations (CFR), or they may be presented as a subset of the National Incident Management System (NIMS) framework. These codes and regulations typically include, but are not limited to minimum requirements for safety, equipment, and training.

The Resource Management Plan (RMP) functions at a very high level as a guideline for planning before or during incidents. These documents are important in providing an understanding of geographical considerations and natural resources; therefore RMPs will typically outline features such as Wildland Urban Interfaces (WUI), mine shafts, watersheds, caves, and the like [11].

Fire Management Plans (FMP) are closer to the incident level but still operate at a fairly high level with respect to the work being done. These documents are generally required to follow guidelines of the Resource Management Plan, and outline additional information regarding the situational awareness of an area to assist in planning for and managing incidents [12]. Fire Management Plans are required for any area with burnable vegetation; they are important documents because if no approved Fire Management Plan exists for an area, then suppression is the only option for dealing with fires [12]. This is undesirable for a number of reasons. Immediate suppression has been shown to negatively affect fire dependent species while also preventing fuel level reduction in large areas of the wildland, and the resulting buildup of fuel levels increases the risk of catastrophic fires at a later time [1]. So it is clear that these documents assist managers in making informed decisions through consideration of fuel levels and ecological dependence on fire, while also focusing on public awareness of fire risks and preparedness in order reduce the risk of catastrophic fire. Further importance of Fire Management Plans stem from the fact that these are developed by people who are most familiar with the area and may be the only incident management personnel permanently associated with the area due to the nature of wildland fire crews moving between vastly different geographical areas to address other incidents [13].

The above mentioned regulations and documents help to guide decisions based on information external to what’s happening in the midst of an incident, and they do not specifically address the exact approach taken or work methods required by an incident. While there is no single answer to providing guidance for these two aspects of fire management, the existence of the Incident Command System provides a solid repeatable starting point for any incident by promoting clear roles and corresponding responsibilities. Those responsibilities as well as proven approaches to past incidents are outlined within Standard Operating Procedures (SOPs) that are developed by individual agencies and incorporate the various regulations mentioned above [14].

1.6 Reasoning for Lean Fire Management

The main discussion in this thesis will cover the Incident Command System and touch on its functional components, such as Standard Operating Procedures, as they function within an overall emergency management framework. This focus on methods and work done at the incident will lend itself nicely to a comparison with a Lean organization and point to possible applications of Lean to the Incident Command System.

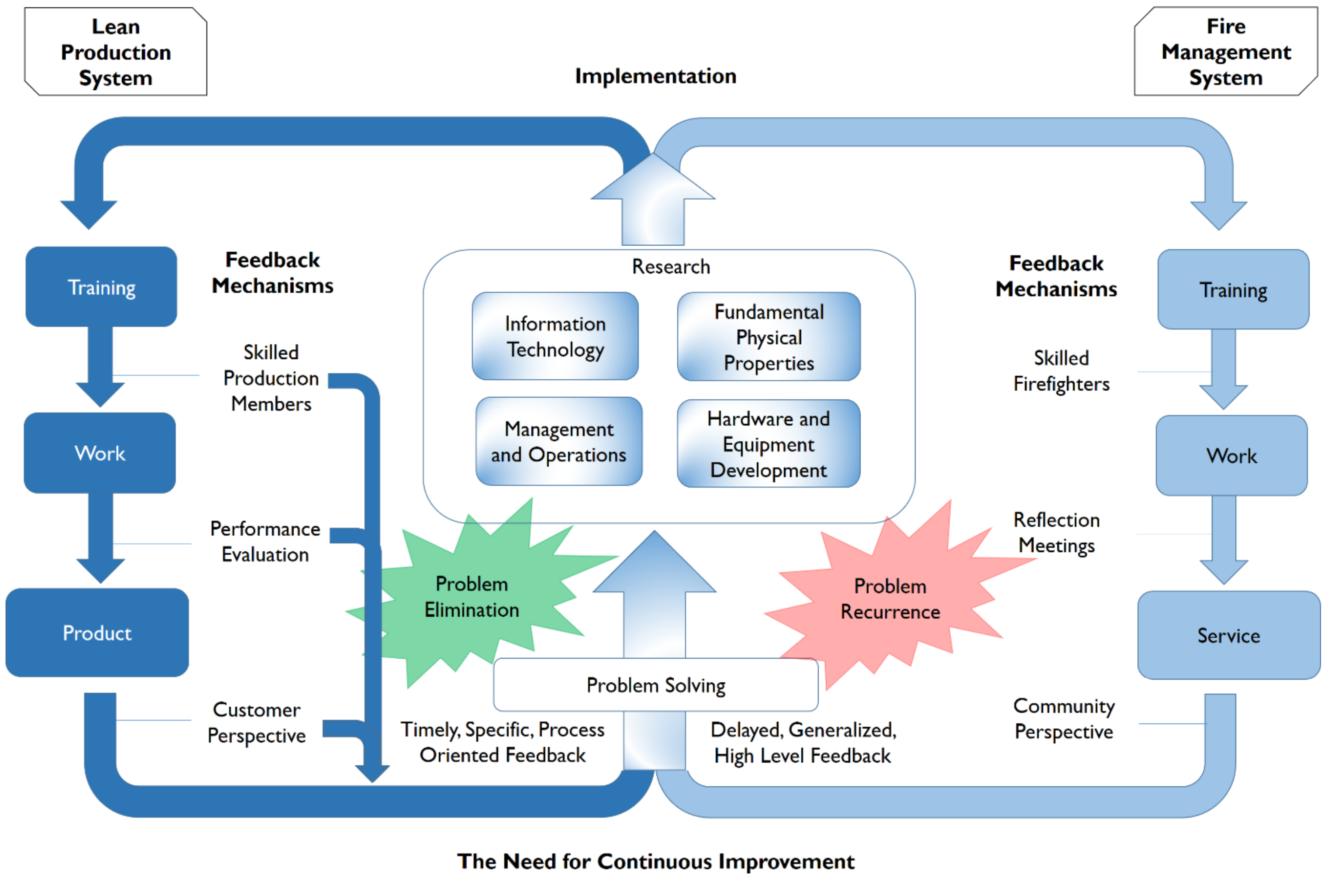


Figure 5: Primary commonalities between the two different systems of Lean manufacturing and fire management. Operational feedback reflects system performance to drive problem solving and research efforts. However, the quality and efficiency of these efforts rely heavily on the system's ability to communicate current conditions. The defining characteristic of a Lean manufacturing management system is its ability to document and communicate this current condition in order to continuously improve.

Figure 5 illustrates that these distinctly different systems share a common goal to provide a product or service. The desire to continuously improve those products or services provides a common drive for both systems to utilize problem solving and pursue various research efforts. The research aspect of this usually promotes the following: better understanding of fundamental physical properties important to the problem, development of information technology to visualize and share information more efficiently, and improvements/implementation of equipment to improve work efficiency/methods. Last but definitely not least, improvements in operations and management of the system itself can be achieved through this loop.

The efficiency of the improvement cycle in Figure 5, for any system, depends highly on current and specific feedback with respect to key functions and processes of the system. Feedback is extremely effective when taken from some form of stable standard because it must provide visibility on current problems in order to properly prioritize topics for research and problem solving [15]. In short, the quality of problems to be solved or presented for research efforts is directly related to the level of understanding that a system has of its capabilities, processes, and products or services with respect to real-time situations. Lean manufacturing is well known to excel at providing this type of feedback for problem solving when implemented properly [16]. Thus the flow of feedback for a Lean system illustrated in Figure 5 is shown as complete to direct that critical information towards the progression of overall continuous improvement.

Within such a broad fire management landscape, the Incident Command System stands out as a focal point because of its importance in everyday fire management. The Incident Command System exhibits the specific goal to promote effective management of hazardous incidents to prevent property losses as well as loss of valuable lives on a day to day basis. It accomplishes this by streamlining the overall decision making process to effectively cope with all aspects of urgency associated with wildland fire, urban fire, or any other hazardous incidents. For wildland fire-based incidents, the decision may be to strictly monitor an incident or to fully extinguish it based on the guidance of the aforementioned regulations and Fire Management Plans. The Incident Command System originated in the 1970s, and has grown immensely over the past 44 years. Though when considering the many generations of firefighters that have served in the United States over the course of its history, the Incident Command System is a relatively new approach to incident management.

CHAPTER 2: LITERATURE REVIEW

2.0 The Incident Command System

The Incident Command System was developed in response to lessons learned during past experiences. This progression can be seen in the timeline illustrated in Figure 6.

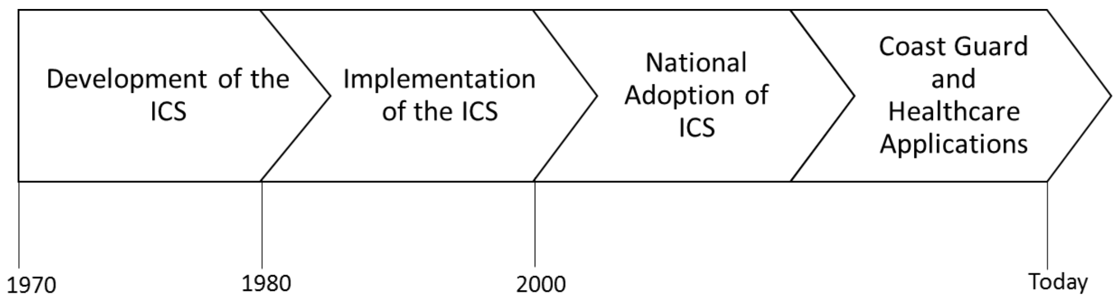
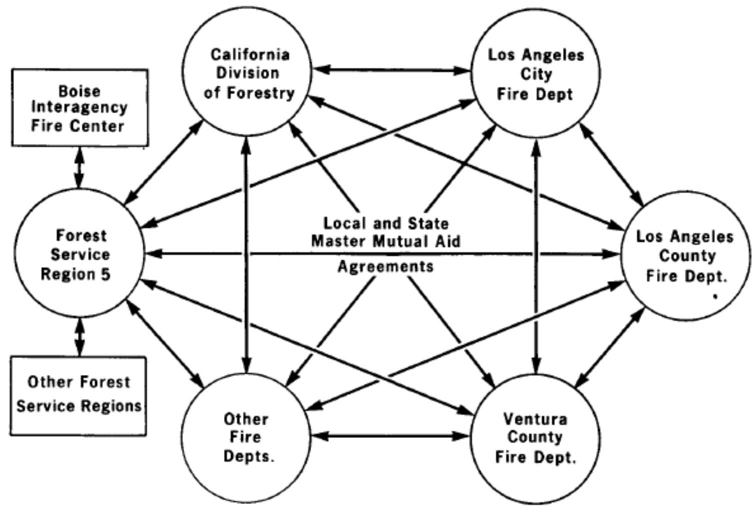


Figure 6: Timeline depicting the history of the Incident Command System.

In the fall of 1970, southern California suffered significant fires that burned over 500,000 acres, more than 700 structures, and caused 16 fatalities [17]. In response, the FIRESCOPE program was developed as "the first practical application of systems design to a major, complex wildland fire management operational problem" [18]. This statement alone is grounds for an industrial or manufacturing engineer to approach this topic with interest. The acronym FIRESCOPE referred to "FIrefighting REsources of Southern California Organized for Potential Emergencies" and as the name suggests, the effort encompassed support from various levels of California's local, state, and federal response community [18]. The FIRESCOPE team discovered that inefficient interagency communications and unclear organizational structures within the fire management system were regularly at fault during out of control incidents [18]. As such, the schematic illustrated in Figure 7 was discussed in Richard A. Chase's technical document regarding FIRESCOPE, and outlines the complicated method of communicating needs related to fire management before FIRESCOPE set out to improve this.



(Figure from Chase, 1980)

Figure 7: Communication for Fire Management before FIRESCOPE. Illustrates complexity of coordination between multiple agencies before the FIRESCOPE project. Schematic developed and discussed by Richard A. Chase in the foundational technical report outlining a new approach [18].

Chase states that in this system each individual agency had to seek out support or approval individually amongst multiple agencies in order to ensure mutual aid if incidents were severe enough to warrant multiple agencies for control [18].

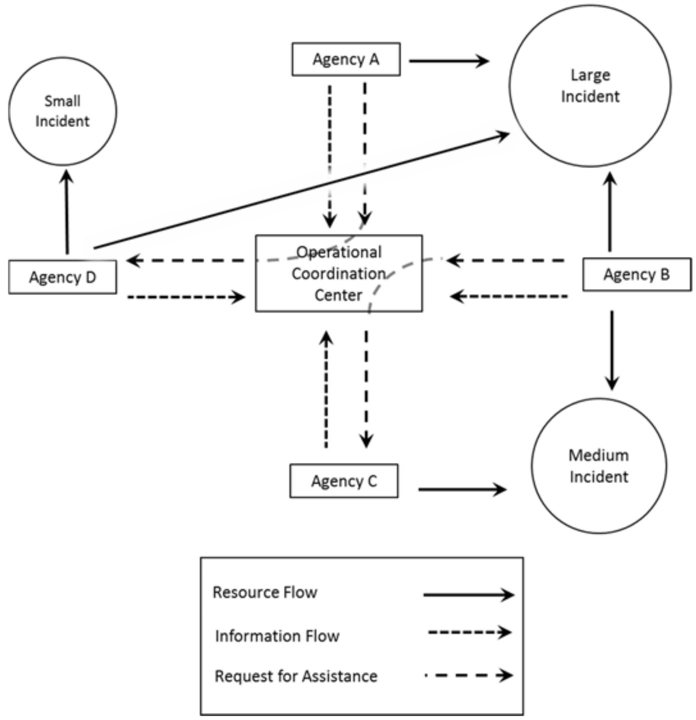


Figure 8: A simplified schematic of the Multiagency Coordination System Proposed by FIRESCOPE. Illustration based on the original schematic discussed within the Chase technical report [18].

Figure 8 illustrates a simplified interpretation of the solution that FIRESCOPE proposed in the Chase technical document, known as the Multiagency Coordination System (MACS). This system illustrates a centralized information center that helps to coordinate and communicate needs during an incident [18]. This concept alone was a major improvement at the time, but the FIRESCOPE proposal did not end there. The Incident Command System was developed to compliment this concept and maintain this same level of coordination and clear communication at the incident level to provide consistent clarity for all levels of involvement with the incident [18].

To achieve the level of clarity required for coordination and efficient communication, the Incident Command System places emphasis on a dynamic organizational structure based on clear roles and standardized terminology [19] [20]. The organizational structure exhibits flexibility during an incident to adjust personnel deployments based on incident severity [20]. Furthermore, a standardized planning process is in place to control adjustments in personnel, plan to meet the objectives of each incident, and determine future management efforts [20]. For the most part, future management efforts are developed further through problem solving efforts before, during, and after incidents to improve response efficiency [20].

2.0.1 Nationwide Implementation

As part of the FIRESCOPE program, the Incident Command System evolved throughout the 1970s and was implemented as a stand-alone incident response system in southern California in the 1980s [18]. Over time, the Incident Command System proved its effectiveness in meeting the demands of each fire based incident with its uniquely scaled organizational structure and facilitation of coordinated resources [21]. Due to the association of wildland fire to urban fire at the Wildland Urban Interface, urban firefighters have also been well aware of the Incident Command System since its beginnings in the 70s. Furthermore, in the early 2000s, the Incident Command System was extended nationwide when President George W. Bush signed Homeland Security Presidential Directive 5 (HSPD-5), which called for a National Response Framework (NRF) to create a uniform management system for all incidents (not just fire related) under the National Incident Management System.

This national adoption of the Incident Command System relied heavily on training and implementation of its ideal usage. As a result, study materials for the

Incident Command System are readily available at the "Emergency Management Institute" website [20], and in-person training programs exist that build upon these online courses as trainees progress. The main facilitators of this training are the Federal Emergency Management Agency (FEMA) and the National Incident Management System (NIMS) who provide the training documents.

National implementation of the Incident Command System has propelled it to become the primary management system utilized within the entire spectrum of emergency management. Therefore, benefits or relationships obtained through improved usage of the Incident Command System for any application should be easily transferrable between urban fire, wildland fire, and other fields of emergency management. It is stated clearly in all training materials and relevant literature that when the Incident Command System framework is used on a day to day basis for each incident, that learning of the process lends it the capability to be effective in providing a stable and scalable framework for all types of incidents [18] [20]. This characteristic of the Incident Command System coupled with its applicability amongst many emergency management systems provides for a flexible approach towards analysis of its characteristics.

2.0.2 United States Coast Guard Application

It's worth noting various successful applications of the Incident Command System that exist within emergency management services such as the United States Coast Guard (USCG). Like fire services, the U.S. Coast Guard is tasked with protecting the lives of many Americans. The Coast Guard primarily performs seafaring duties to ensure the safety and security of the nation's coastlines from various threats. The Coast Guard's focus on public safety means it was impacted by the signing of Homeland Security Presidential Directive 5 to implement the Incident Command System framework in 2005.

While implementing the Incident Command System, the U.S. Coast Guard developed and published their own issue of an Incident Management Handbook which states in the opening section that, “during Incident Management Handbook development, it was recognized that 80% of response operations share common principles and procedures…the other 20% are unique to the incident” [22]. This statement lends great credibility to the implementation of the Incident Command System to bring some level of stability and clarity to what is often considered highly variable and chaotic working conditions. The realization that 80 percent of response efforts are similar implies that there is a basis of repeatability in their processes. This repeatability can be documented and improved similarly to how stable processes are improved within a Lean system. In support of this statement, the handbook also directs members of the Coast Guard to where they can access multiple job aids that have been developed and supplied for each standard role within the organization [22].

The Coast Guard is well known for outstanding work within emergency response as well as search and rescue operations even before adoption of the Incident Command System, and examples of this are easily available for illustration of this fact [23]. However, while the best efforts are exerted by all responders within emergency management, the occurrence of more severe incidents may lead to an influx of people affected by that incident to require hospital treatment. This is where the Hospital Emergency Incident Command System (HEICS) comes into play.

2.0.3 Healthcare Application

Within the healthcare community the concept of “pre-hospital emergency management” encompasses any or all incidents that are managed by other emergency response agencies that may increase demands on hospitals as well as incidents that involve the hospital directly [24] [25]. The Hospital Emergency Incident Command System is based on the original “FIRESCOPE ICS” [24] and gives an excellent platform for hospital based incident management due to its flexibility and coordination to “function as the ‘central nervous system’ in directing all response activities” [24]. The HEICS is also evolving within the healthcare industry to standardize response to new issues that have appeared over the years such as pandemics due to infectious disease and consideration of the mental effects associated with large incidents on all persons, including responders and medical staff members [25].

As can easily be seen from these examples, application of the Incident Command System amongst all response agencies as well as healthcare has the capability to provide a coordinated effort to helping victims of incidents from the beginning of an incident throughout their recovery. This speaks volumes of the flexibility and adaptability of the Incident Command System. However, it must be noted that the fire services in the United States have been using the Incident Command System since the very beginning of its development. So, for the purposes of this thesis, applications of the Incident Command System within the firefighting community will be the primary subject when analyzing capabilities of applying Lean manufacturing principles and practices. Those principles and practices will be introduced and discussed in the following sections.

2.1 The Toyota Production System

The Toyota Production System was developed in response to lessons learned during past experiences, and thus, shares similar background with the development of the Incident Command System. The development and spread of Toyota Production System principles can be seen in the following timeline of Figure 9.

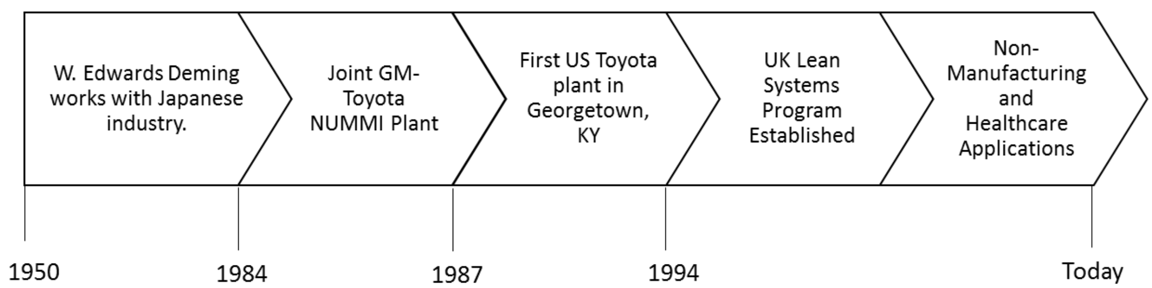


Figure 9: Timeline depicting the history of the Toyota Production System.

The tough economic climate of post-World War II Japan led Japanese manufacturing companies to fight for their very survival. In 1950, American scientist and statistician W. Edwards Deming traveled to Japan to assist post-war recovery efforts. Deming introduced Japanese officials to the concept of statistical quality control [26] and the idea that focusing on "built-in" quality rather than inspection could increase the quality of products or services without increasing costs [27]. Deming also introduced the Japanese to the Plan-Do-Check-Act (PDCA) learning cycle (shown in Figure 10), as well as his "14 Principles of Management" [27], both of which serve as the foundation for managing the ability to achieve and sustain built-in quality.

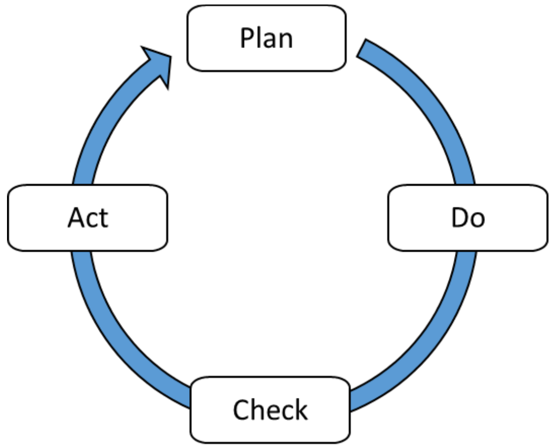


Figure 10: The Plan-Do-Check-Act learning cycle taught to Japanese industry by W. Edwards Deming.

Eventually these ideas were embraced and successfully implemented into many Japanese companies, including Toyota, who continued to apply them, eventually developing the Toyota Production System (TPS or Lean manufacturing). The foundation of a Lean system is standardization and revision of those standards through diligent problem solving to resolve abnormalities, to reduce/eliminate waste, and to continuously improve the system's ability to provide products or services [28] [29].

2.1.1 Implementations in North America

The transition of the Toyota Production System from Japan to North America is marked by a peak in interest by North American manufacturing companies after several key occurrences over time. For example, in 1984, General Motors (GM) and Toyota partnered together to open the New United Motor Manufacturing Incorporated (NUMMI) plant, an endeavor in which Toyota contributed principles of their production system towards operation during the joint venture [30]. The NUMMI plant was a second attempt at operations within a manufacturing facility in Fremont, California that had been shut down and considered to be a lost opportunity [30]. Although the issues of productivity, quality, and low employee morale plagued the former GM-Fremont plant before the partnership, Toyota pushed to re-hire all former employees and maintain union contracts with each employee to produce vehicles [30]. The NUMMI plant experienced better worker morale, and in turn improved quality and productivity issues due to the people oriented philosophy of the Toyota Production System [31]. A philosophy in which they respected the worker and allowed them to stop the line and question possible defects and abnormalities of their processes [31].

The 1987 opening of Toyota Motor Manufacturing Kentucky (TMMK) in Georgetown, Kentucky marked the first major production facility in North American and was Toyota's first venture into the U.S. market on their own. TMMK remains as the largest Toyota plant in the U.S. and since opening, the company has opened plants in Indiana, Texas, Mississippi, Alabama, and West Virginia.

Later, in 1991, the term "Lean manufacturing" first appeared in a book titled "The Machine that Changed the World" [32]. This book is based on research conducted at the Massachusetts Institute of Technology (MIT) regarding the development and inner workings of the Toyota Production System [32]. This exposure to Toyota's continuous improvement efforts led many people within the manufacturing industry to take notice.

As it stands today, the Toyota Production System places a great deal of importance on "providing products and services with craftsmanship, pride, zeal, history, spirit, joy, and more" [29]. The company strives to promote lifelong learning in its employees to produce well-rounded professionals; this effort intends to develop employees who possess not only well-developed specialized technical skills but also overall knowledge and keen interest in continuously improving their work [33].

Fujio Cho is well known as a visionary with respect to Toyota and the Toyota Production System. It is well documented that Mr. Cho focused on building consensus, and developing people based on their skills as well as their particular interests. Mr. Cho's philosophy is summarized in the following statements collaborated from various sources:

> "A company must provide service to society, and the way a company must go about that is to produce good products honestly and consistently without compromise [29], offering service-oriented concepts to create a highly effective and efficient modern system consisting of people, information, machine and material" [33] [34].

It was this drive to provide service to society that promoted Mr. Cho to play a large role in the development of the University of Kentucky's Lean Systems Program.

2.1.2 The University of Kentucky's Lean System Program

The success of the Toyota Production System and several attempts to understand its inner workings by competitors and researchers alike prompted Mr. Cho's vision to promote a partnership between Toyota and the University of Kentucky in 1994. The University of Kentucky was chosen due to its close proximity to Toyota Motor Manufacturing Kentucky, as well as its excellent curricula regarding Science, Technology, Engineering, and Mathematics (STEM). Therefore, apart from actual Toyota experience, the University of Kentucky's Lean Systems Program (UK-LSP) is the closest resource available for deeper understanding of Lean manufacturing. The Lean Systems Program provides a variety of courses on Lean manufacturing principles and practices created through 20 years of close collaboration with Toyota. During this time, the program has served more than 20,000 people from different types of organizations including manufacturing, food service industry, healthcare and public services, as well as education.

To maintain congruence with the Toyota Production System at its source, the UK Lean Systems Program operates from a pool of retired Toyota employees from various levels within the organization who teach Lean manufacturing principles as they have learned them during their time within Toyota. Furthermore, the Lean systems Program houses a current Toyota executive who serves in residence with the Lean Systems Program for a 2 year period. This opportunity gives the executive valuable practice in applications of Toyota Production System principles across a broader audience to include clients not affiliated with Toyota. Exposure to an academic environment also promotes Mr. Cho's vision of developing the academic understanding of the Toyota Production System. Furthermore, the executive in residence helps to promote continuous improvement within the Lean Systems Program itself through application of Toyota Production System principles towards the program's processes, functions, and goals. After the executive's two year term is done, another executive, possibly from a significantly different area of management within Toyota, will rotate in providing further development. This provides many perspectives on the product provided by the Lean Systems Program.

The value added by the UK Lean Systems Program can be seen when reviewing their standard definition of what Lean should mean to an organization. The Lean Systems Program's definition of "True Lean" is meticulously crafted and more clearly illustrated as the breakdown of the following 5 points:

1. The group by themselves,
2. use systematic problem solving,
3. to improve the work they do,
4. towards achievement of the company's targets and goals,
5. when and only when the company culture is the reason the improvement occurs.

    – *The Definition of "True Lean"* [28].

Each point of this definition holds a certain principle of TPS. The opening point focuses on the people doing the work. This intentional placement of putting them first in the definition of "True Lean" symbolizes their importance in the system. The second point states that there exists a method of problem solving used systematically throughout the organization. The third point stresses the focus on continuous improvement but only within the work that one is responsible for, not in other sections outside of their control. The fourth and fifth points outline that the company's culture is what drives the system towards achieving the measurable targets and goals set by the company. These last two points also allude to a capability of assessing performance within the system by communicating it effectively to the workers, as well as upper level management, to stimulate the improvement process and ensure value added improvements. This is achieved through effective development and visualization of Key Performance Indicators (KPI) encompassing the company's targets and goals. Effective usage of Key

Performance Indicators can allow users of the system to quickly and efficiently identify gaps for improvement. The approach for organizational transformation at the University of Kentucky's Lean Systems Program is unique, and this definition illustrates the overall intention to reach beyond common misconceptions of what practicing Lean manufacturing means in any setting. That is, rather than focusing specifically on tools or an ability to save costs, the program develops curriculum that brings about consideration of society, company culture, industrial psychology, principles of organizational learning, and respect for people to the forefront of Lean transformation.

2.1.3 Lean Healthcare and Non-Manufacturing Applications

Healthcare organizations have had some success implementing Lean principles and practices to enable and sustain continuous improvements. Graban [35] discussed that various hospitals have been able to reduce operational considerations through Lean principles and practices. This was evident in reductions related to the time it takes for lab results to be processed, decontamination time for instrumentation, and other aspects that reflect negatively on patient satisfaction (blood based infections due to intravenous devices, patient wait time, or the patient's length of stay). Graban also notes:

> "With advances and systematic improvements in aviation safety, passengers in the general public take it for granted that they will arrive safely at their destination; we should hope for similar advances in healthcare so patients can take it for granted that they will not be harmed in hospitals" [35].

This perspective is one that drives the incorporation of Lean in healthcare and illustrates implementation into another industry, aviation safety.

The aviation safety industry has been fairly successful in its transformation to Lean manufacturing. The Maintenance, Repair, and Overhaul (MRO) industry is defined as the industry responsible for maintenance and restoration of active aircraft functioning at an airline so they maintain safe performance of their intended functions [36]. These organizations have benefitted from the implementation of Total Productive Maintenance (TPM) as well as other Lean principles to improve their efficiency and eliminate waste [36]. The successful applications seem to be prominent for large aircraft MROs, and some struggles have been encountered when applying Lean to organizations that deal more particularly with small aircraft due to limited resources and low volume [37].

More towards the business aspects that Lean can be useful for, it must be noted that the well-known and highly sought after 8 step problem solving process that is used within Toyota is simply referred to as the "Toyota Business Practice" [38]. This method is not only used for solving problems at the production floor, but is used for improving processes in other aspects of the organization such as the Human Resources department, Accounting and Finance functions, and the management of hiring and training new employees [28] [38]. This isn't to say that the 8 step problem solving method can be used standalone within these departments, but indicates that it is only part of a larger management directive inherent to the Toyota Production System. The focus on Deming's Plan-Do-Check-Act learning cycle encourages the entire management of the system and the problem solving process follows this cycle strictly as well.

The idea that the Toyota Production system is applicable in all management spectrums is also supported by a comment in Phillip Marksbury's book "The Modern Theory of the Toyota Production System." Marksbury states that the Toyota Production

System may better be described as the “Toyota Management System” to avoid much confusion [39].

These factors illustrate the Toyota Production System’s capability and flexibility to be applied in any management setting. This is rooted deeply in the Toyota Production System’s goal to provide quality to the customer, where customer can be defined as the next receiving process in the overall production of a product or service, as well as the final customer who receives the final product or service [28] [29].

2.2 Organizational Learning Theory

System such as the Incident Command System and those who use it must continuously improve response efforts, and Organizational Learning plays a key role in that effort. The dynamic Incident Command System meets its goals through a best practices type of approach, which relies heavily on its ability to learn from previous incidents [14]. This indicates that learning occurs not only on an individual basis, but also at an organizational level [40]. The application of Lean principles and practices have been shown to greatly increase individual learning, and by extension, organizational learning [41]. Because of this, Toyota has been called “the gold standard” of learning organizations [16]. The Plan-Do-Check-Act learning cycle encourages the continuous improvement typical of learning systems because of its reliance on timely operational information feedback [15] [42] [43] [44]. Operational feedback relies on how well a system is defined and understood by its users in order to identify problems and resolve them quickly. This leads neatly into Chapter 3, where investigation into the systems serves to promote an encouraging discussion of similarities alongside illustration of gaps between Lean and the Incident Command System.

CHAPTER 3: DISCUSSION

3.0 Systematic Comparison

The need to develop an ever-increasingly effective learning organization provides a common goal for both Lean manufacturing and Incident Command System applications. This indicates that the Incident Command System could benefit in its efforts for continuous improvement by adopting Lean principles. To support this claim, fundamental principles that govern the Incident Command System, as well as its key functions and components, needed to be examined closely for comparison. Figure 11 provides an overall comparison of the organizational structures for discussion.

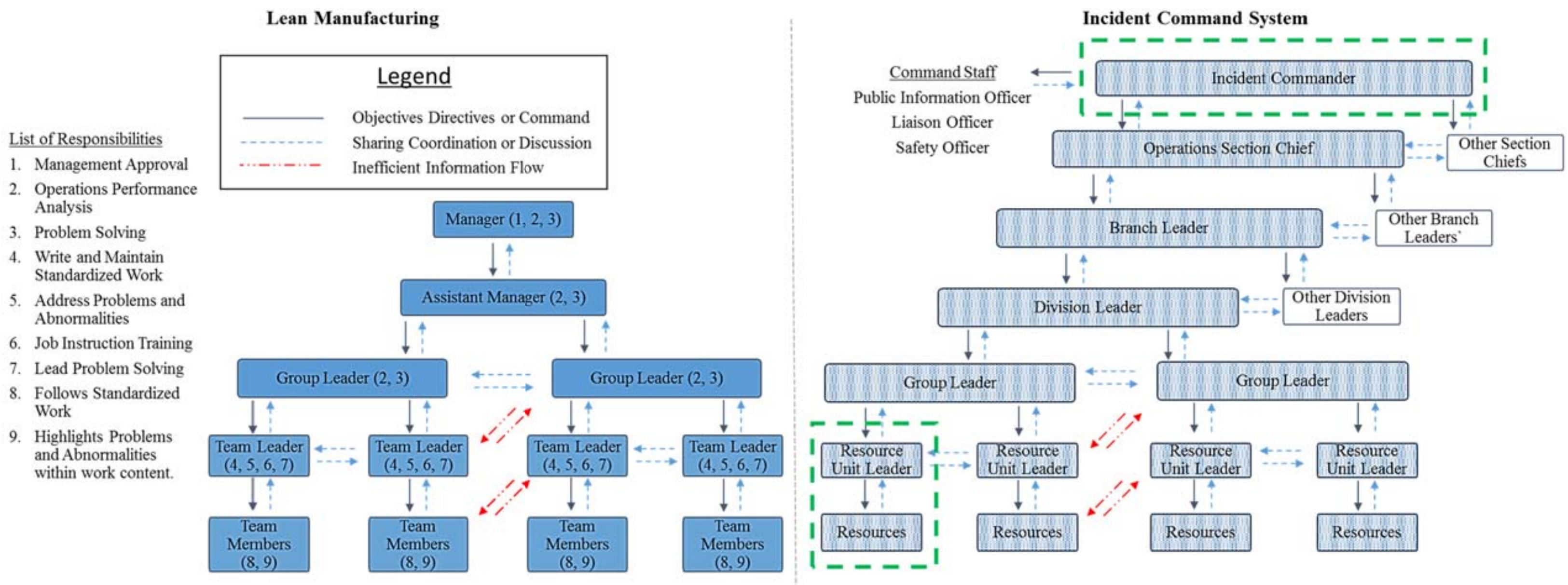


Figure 11: Standardized structure and roles within Lean manufacturing (Left) [28] *and the Incident Command System (Right)* [20]. *Illustrates span of control, communication flowing in both directions, and coordination taking place between supervisors of each group in both systems. The diagonal (dash-dot-dot) arrows illustrate improper communication within these systems. Listed to the left, the Lean structure clearly associates each role with certain responsibilities* [28]. *This is a partial representation of either system's entire structural hierarchy for descriptive purposes only. Given the Incident Command System's dynamic nature, the dashed boxes illustrate required roles to initiate formation of the structure* [20].

The comparison shown in Figure 11 illustrates organizational structures and direction of flow for communication in both Lean manufacturing and the Incident Command System. Well defined span of control, roles, responsibilities, and communication are key components in the success of both systems.

3.0.1 Standardized Structure and Roles

Figure 11 illustrates that the functional groupings within an Incident Command System's response framework are typically comprised of 3 to 7 individuals per supervisor [20]. Similarly, in a Lean system the same type of control span is employed for Team Leaders to have around 4 to 6 Team Members reporting to them. This limitation provides ease of management within a system without underwhelming or overburdening management, and gives more clarity to role definition and individual contributions [45].

The organizational structure of Figure 11 for a Lean system depicts roles that are intended to guide workers who perform the same job or work rotations every day. In contrast, the Incident Command System's organizational structure is extremely flexible to compensate for high variability in the demand of resources for each incident. In either case, the existence of some standard roles within each structure provides stability.

The Incident Command System's structure typically begins with one small group of responders at the resource level, which is illustrated by the dashed box in Figure 11. From there the situation is assessed and a decision is made. The determination of whether more resources are needed, as dictated by the incident, prompts the structure to expand into the hierarchy shown in Figure 11 [20]. The Incident Commander (IC) role, shown highest in the hierarchy, is a critical role assuming responsibility for management of the incident. While the incident is small with respect to the number of people responding, the Incident Commander role may be filled by the leader of the first responding resource; if the incident does not escalate, this person may remain solely responsible for all aspects of management [20]. However, as the incident escalates, more resources are required to assist in incident management. If the number of people that the Incident Commander is directly responsible for (span of control) is exceeded, various section chiefs may be "activated" by assigning qualified personnel to the role in order to distribute the work and maintain appropriate span of control [20]. Otherwise, if the incident becomes significantly more difficult to manage, the role of Incident Commander is transferrable to an individual who has more experience with larger incidents or more specific incidents such as wildland fire or the presence of hazardous materials at the incident [20].

Each section chief assumes responsibility for managing some aspect of response whether it be within an Operations, Planning, Logistics, Finance, or Intelligence section of the framework [20]. The section chiefs will act within their scope of responsibility and report back to the IC periodically [20]. The Operations Section Chief and roles assigned within it are illustrated in Figure 11. However, due to the inherent nature of understanding incidents and determining approaches to resolving them, the Planning Section Chief is one of the first roles activated within the organizational framework to guide operations [46]. It must be noted that Planning, Logistics, Finance, and Intelligence sections have different role assignments under them, and for simplicity these are not illustrated in Figure 11 [20].

Various definitions for specific groupings exists to distinguish different modules of the Incident Command System's organizational framework. For example, under the Operations Section Chief, different "Branches" are groups working on the same fire with each branch providing a specific service (e.g. suppression, search and rescue, medical services) to contribute towards controlling the incident and protecting the population [20]. Under any given Branch, the term "Division" or "Group" is used to define how a set of resources is contributing to an incident.

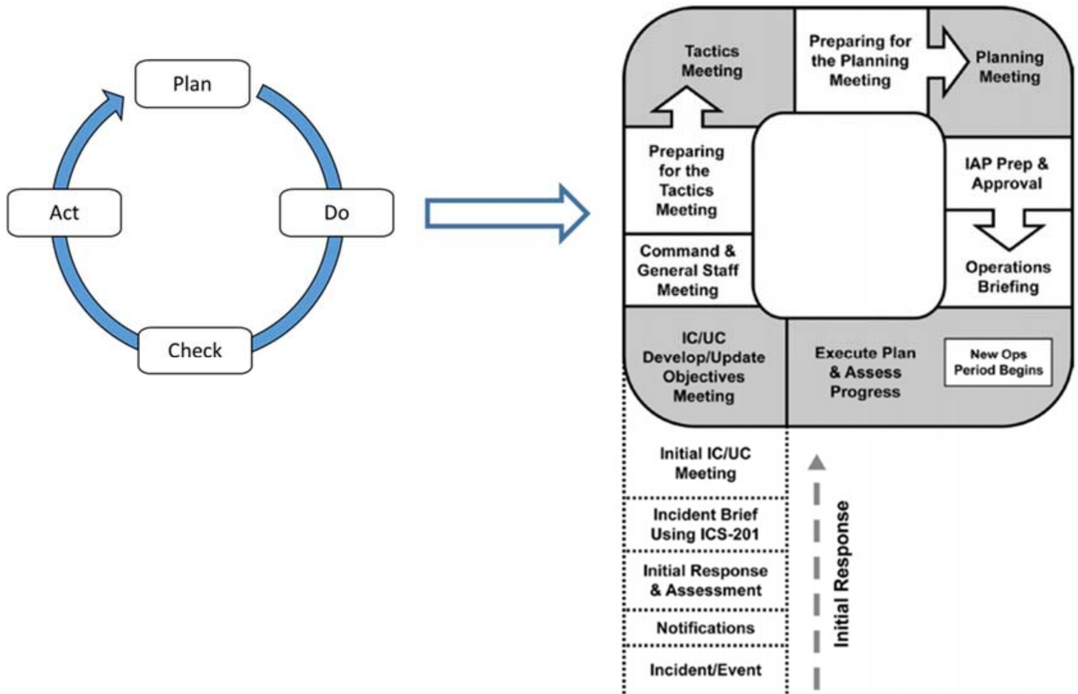
Divisions may be comprised of similar or different types of resources with the main distinguishing characteristic being the geographical location of their operations (e.g. interior/exterior of a building fire, or north, south, east, west side of a large wildland incident) [20]. Under a Division, the term "Strike Team" or "Task Force" is used to distinguish how working teams are comprised. Strike Teams would have similar resources to contribute to an incident (two hose trucks), while Task Forces would be comprised of mixed types of resources (hose truck/ladder truck) [20]. Further, a "Group" consists of functionally similar types of resources working on the incident within a Division [20].

This design for an expanding framework is unique to the Incident Command System. However, a similar level of flexibility is exhibited by the Toyota Production System in its organizational design. The organizational structure of a Lean system is based on providing support to frontline production Team Members, and a good example of this can be seen in problem solving. Problems are addressed directly at the process from a point of occurrence by a Team Leader, and upon escalation they are communicated to higher levels of a Lean organization [28]. This allows problems to be resolved at the appropriate level using the right amount of effort at the right time to accomplish the task.

This type of clarity with respect to role definition provides responders with the ability to function in a stable framework while communicating quickly and efficiently between various functional modules during the midst of an incident. To facilitate usage of this structure, the situation must be understood and planning must take place to expand or reduce resources used in the incident appropriately.

3.0.2 Planning and Communication

The planning process that takes place within an Incident Command System environment is known as “The Planning P” [47], and this method is geared towards changing the purely reactive mode of initial response into a more proactive mode of gaining control or reducing an incident [20]. Similar to how an Operations Section Chief is activated in Figure 11, a dedicated Planning Section Chief could be activated and focus primarily on the planning process. Their main goal would be to coordinate with other Section Chiefs (Operations, Logistics, Finance, and Intelligence) to collaborate goals into an Incident Action Plan (IAP) for the incident [20] [47].



(Planning P from training.fema.gov – PlanningP.pdf)

Figure 12: Illustration of "The Planning P" planning process of the Incident Command System. Shows the planning process as a cycle that occurs after initial response takes place [47]. *This cycle is representative of one operational period where meetings take place to develop, update, and revise the Incident Action Plan. The cycle also resembles a PDCA cycle.*

The Planning P shown in Figure 12, illustrates the meetings required between various section chiefs to share information throughout the organization. Therefore, it can be inferred from previous discussion of roles that, if the incident does not warrant section chief activation, this would be manageable by the Incident Commander. This is because coordination of efforts will be less complex, and development of the Incident Action Plan may require fewer meetings or steps of the cycle. Most importantly, this cyclical method of planning and coordination represents a learning phase similar to the Plan-Do-Check-Act learning cycle which is inherent to the Incident Command System overall. This planning method plays a significant role in the expansion and reduction of operational resources [46] as well as the problem solving process which is addressed later in this chapter. For more information please refer to "The Planning Process" document found in Appendix A.

The desire for two-way communication represented in Figure 11 for both systems indicates that information should come from the top down as well as from the bottom to the top. This is logical given that the current condition should affect decision making in both systems. Furthermore, collaboration amongst certain adjacent roles in Figure 11 is highly encouraged in each system where applicable. For instance, in a Lean system, Team Leaders from different work groups would collaborate to resolve issues that their respective Team Members are dealing with (e.g. receiving defects from a previous process) instead of team members themselves as they are busy with their work [28]. Similarly, in the fire services, any issues across different groups would be communicated through respective supervisors in the system to resolve the situation. In order for this communication to be efficient the corresponding roles must be accompanied by some method of informing personnel of their responsibilities.

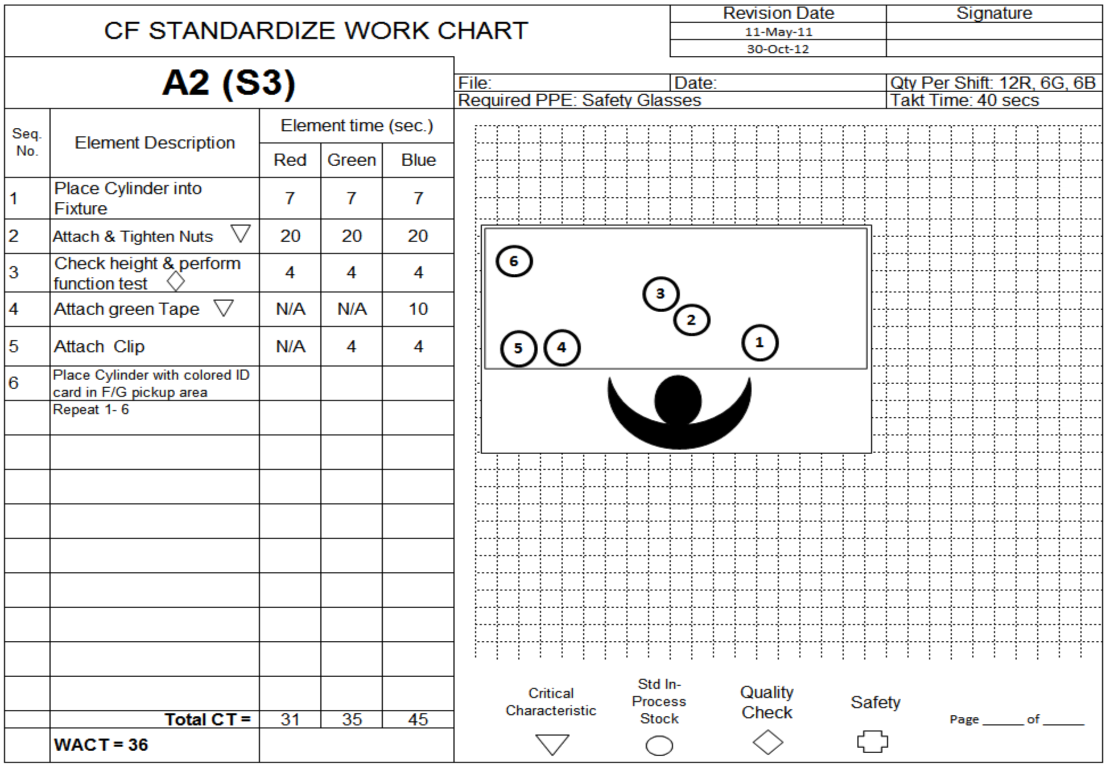
3.0.3 Standard Responsibilities and Documents

In Lean systems, Standardized Work (STW) is developed and maintained, preferably by the Team Leader, to promote stability while providing opportunities to define and eliminate abnormal conditions that burden the workers [28]. As previously mentioned, the tasks of the frontline production members in a manufacturing environment often contain low variability. Standardized Work Charts such as shown in

Figure 13 are appropriately rigid for this. Standardized Work Charts display the time required to complete work in order to meet customer demand (often referred to as “Takt Time”) as well as the elemental work method and standard amount of work in process for the worker to complete their tasks [28].

An abnormality or abnormal condition is typically understood to be present when a worker has to adjust their normal method of work to avoid a problem, has to stop their work, or has to do something that isn’t described in the Standardized Work Chart for his/her work station. This type of struggle is clear to the worker who is experiencing it, but only if the standards for that process are well defined and followed. This awareness gives the Team Member an opportunity to stop the line or call for help to remedy any abnormalities. Also, Standardized Work Charts are intended to be displayed where they are easily viewed by the Team Leaders, Group Leaders, and higher levels of the organization [28]. This provides quick assessment of current conditions to show how well the Team Member is able to keep pace with production, while also providing an opportunity to observe any abnormalities that are occurring. This visibility along with regular Team Leader assessment provides the ability for the system to react faster and resolve abnormalities more efficiently to regain normal working conditions.

The two following figures are displayed to illustrate the Standardized Work Chart (Figure 13) as well as the supporting Standard Work Element Sheet (Figure 14). These documents are present within the laboratory function of the University of Kentucky Lean Systems Program to instruct trainees on Standardized Work. This laboratory strives to simulate a production environment progressing through various defined stages in Lean manufacturing development in order to allow trainees with an opportunity to use tools associated. These documents represent an assembly function within that environment.



CF STANDARDIZE WORK CHART

Revision Date	Signature
11-May-11	
30-Oct-12	

A2 (S3)

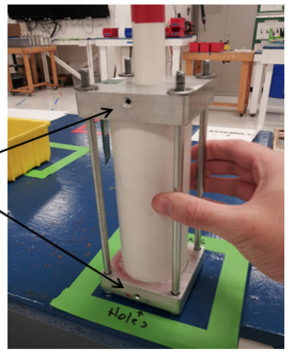
File:	Date:	Qty Per Shift: 12R, 6G, 6B
Required PPE: Safety Glasses		Takt Time: 40 secs

Seq. No.	Element Description	Element time (sec.)		
		Red	Green	Blue
1	Place Cylinder into Fixture	7	7	7
2	Attach & Tighten Nuts ▽	20	20	20
3	Check height & perform function test ◇	4	4	4
4	Attach green Tape ▽	N/A	N/A	10
5	Attach Clip	N/A	4	4
6	Place Cylinder with colored ID card in F/G pickup area			
	Repeat 1- 6			
	Total CT =	31	35	45
	WACT = 36			

Figure 13: Standardized Work Chart depicting work methods, Takt time, and Standard Work in Process required for completing one cycle of work towards production of a product. Visual representation of work layout depicted with numbers correspond to steps in the work method. This provides a stable repeatable starting point for work each time. However, the standard layout must be sustained for this tool to be effective [28].

REVISION TABLE		STANDARD WORK ELEMENT SHEET (SWES)				Page: 1 of 1
Rev. Level	Date	Shift	Team Leader	Supervisor	Area/Call/Dept.	
	11/7/2012				Station No.	A2

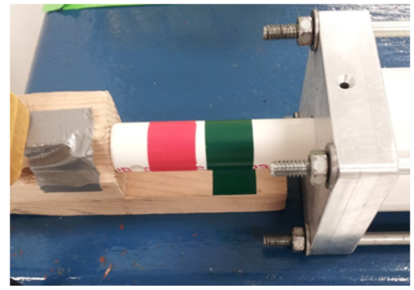
A



Air ports

Hand position when picking up product

B



SEQ	STEP (What)	SYM	KEY POINT (How)	REF	REASON (Why)
1	Place cylinder into fixture		Pick up from bolts, place in grooves	A	Maintain proper seating
2	Attach and tighten nuts	▽	Tighten on diagonals, three times		Avoids loose fit
2	Attach & tighten nuts	✚	Move the drivers one nut at a time		holds cylinder in place
3	Check height	◊			
4	Perform function test	◊	Test both top & bottom ports with air	A	Meets customer spec
5	Attach green tape	▽	Align Rod to jig to ID tape location	B	Meets customer spec
6	Attach clip				

(SYM): ✚ Safety ◊ Quality Check ▽ Critical File:

Figure 14: The Standard Work Element Sheet illustrates each step of the work method described in the Standardized Work Chart and provides further information regarding key points how as well as reasons why something is done. For this example, visual symbols (cross, diamond, or inverted triangle) indicate steps in the method where safety may be of concern, where quality needs to be checked, or where a step is critical for meeting the specifications of the product during the production process [28].

Standardized Work Charts are often supported by Standard Work Element Sheets (SWES) illustrated in Figure 14, which breaks down more complicated work elements to describe how they are done and provides clear visuals alongside key points as to why they are done [28] [48]. It can be seen by the revision dates of these documents that the Standard Work Element Sheet has been revised more recently than the Standardized Work Chart. This reveals an important relationship between these two documents as well as continuous improvement in general. The Standardized Work Chart is comprised of broad steps showing an overall method for assessment while the Standard Work Element Sheet provides the details of those steps for in depth understanding. Hence, changes that occur in smaller increments are preferable to larger changes because they generally won't change the overall work being done, but will affect details and understanding of how part of the work is done. These changes would improve detailed aspects of the methods outlined in Standardized Work Charts without drastically affecting the Team Member performing the work. When a large number of minor changes have accumulated regarding the details of work, then the overall method may be revised to reflect the current condition and new work method.

This stability reduces the need for constant in depth training on a process with experienced workers, because the method remains largely familiar to the worker. Exceptions to this occur when equipment, product design, or quality requirements change, but overall, it is desired to have a good stable process that's well documented and built from the best method available [28] [48]. This gives way for good results in a Lean system based on the idea that a good process will produce good results and that improvement of that process will improve results further [28].

The decision based work content performed by members of higher levels within a Lean organization effectively limits the application of these approaches towards standardizing their processes. For these instances, Standardized Procedures may be developed with less strict adherence to exact step by step methods and intended to serve as a general guideline [48]. This can provide stability regarding how to approach situations, keep the individual focused on what to look for in a given situation, and ensure that the person knows how often the situation should be reassessed [49]. A simple example of this type of work is a general production maintenance scenario represented in Figure 15.

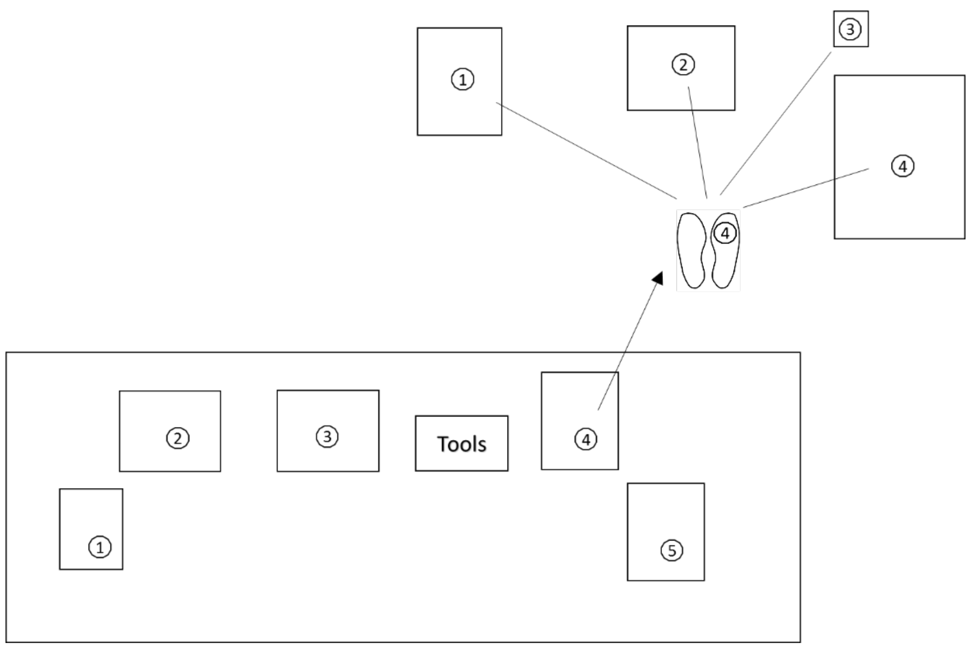


Figure 15: Simple scenario of production maintenance [50].

In this scenario, the individual performing maintenance checks has 5 machines to consider. The figure illustrates that at the fourth machine there are four things to consider, this machine may have components to inspect, gauges to read, or other regular preventative maintenance tasks. Having this checklist of things to take into consideration allows the worker to approach the work the same way each time. Also it's easily apparent from clear diagrams such as Figure 15, that the third item to investigate is somewhat obscured. Having some record of what to check when investigating a machine can provide the ability to ensure all tasks are accomplished, but also provides a baseline of stability which can be improved upon. In this case, the third item on the checklist could be moved or improved to provide a quick visual without having to go behind the fourth item for access.

The overall goal for decision based standards are the same as with Standardized Work Charts and Standard Work Element Sheets. This is to focus on the process, stabilize it, standardize it, and look for future improvements to ensure incrementally better results. However, it can be seen that the level of rigidity presented in the Standardized Work documents of Figure 13 and Figure 14 would be restrictive to firefighters and most likely impossible to maintain due to high fluctuations in work content and time.

Methods for production maintenance bear striking similarities to how the fire services approach assessing a situation. For example, a standard method for assessing problems with a machine may be the inspection of products being made by the machine, as particular defects may indicate problems with specific components of the machine. Production maintenance also utilizes oil sampling in order to better understand machine conditions that may be present when oil is dirty, burnt, or contains shards of metal [50]. Similarly, in the fire services smoke reading is practiced in order to predict the location of a fire within a building as well as the severity of a fire based on the smoke's color, density, velocity, and turbulence [51]. This technique can provide first responders with vital warning signs to avoid possibly dangerous situations. These approaches provide quick and immediate feedback about a situation and are practiced mainly because of the brevity and accuracy by which a person can assess a situation to discover the main cause of a problem.

Methods of standardizing the overall response efforts of fire services may come in the form of regulations or codes proposed by local, state, or federal entities as discussed in the Introduction. These typically result from a legislative process, and tend to work towards improving aspects of safety and performance. For example, the Code of Federal Regulations requires that firefighters use Self Contained Breathing Apparatus (SCBA) for respiratory health during incident response. While regulations tend towards general improvement, they take time to complete from the standpoint of identifying a problem and then going through necessary channels to resolve it, therefore a time lag exists before regulations and codes are implemented that could improve day to day operations. However, the amount of these regulations, codes, and legislative entities are numerous for firefighters. Naturally, some baseline of stability is critical to reducing the complexity placed upon firefighters in their duties.

The fire response community strives towards process control throughout the entirety of response from the sizing up of an incident to the determination of when an incident is under control. These methods are generally referred to as Standard Operating Procedures (SOP), or similarly Standard Operating Guidelines (SOG), the latter being used to counter any misconceptions that two unique incidents should be handled exactly the same. These procedures are developed by each department to incorporate regulatory standards ensuring compliance [14]. Furthermore, departments are not limited in their capability to adjust Standard Operating Procedures for improving past regulations in order to meet department specific goals or to build upon “consensus standards” [51], which may be unrelated to regulations but understood to be best practices learned from past incidents.

3.0.4 Examples of Standard Operating Procedures in Fire Services

Standard Operating Procedures in the fire services are critical to keeping responders on the same page to bring some form of repeatability and a proactive mindset to an occupation that deals with highly variable and reactive situations. Numerous Standard Operating Procedures are developed within each fire department, and some even address how to implement and follow the framework of the Incident Command System. There are some which incorporate federal requirements, such as the aforementioned required usage of SCBA and the exposure limits for toxins emitted from combustion. While others improve upon the overall body of knowledge related to regulations, for example, outlining best practices for the usage of SCBA under heavy operations. Other Standard Operating Procedures may provide guidance on operational tasks, such as approaching and sizing up an incident, or keeping accountability of personnel while inside structures during incidents [51].

The Standard Operating Procedure that’s typically used for the initial response of an incident exists to provide a repeatable look at an incident, such as a multiple story building on fire. During the approach and size-up of an incident, departments position the

Engine truck with the hose for suppression forward of the building for two reasons: they are able to view multiple sides of the building on approach for size up of the incident, and they save room at the front of the building for a Ladder truck to access the building [51]. Alongside this, departments designate sides of the building with letters or numbers for clear communication; these are illustrated in Figure 16 and Figure 17.

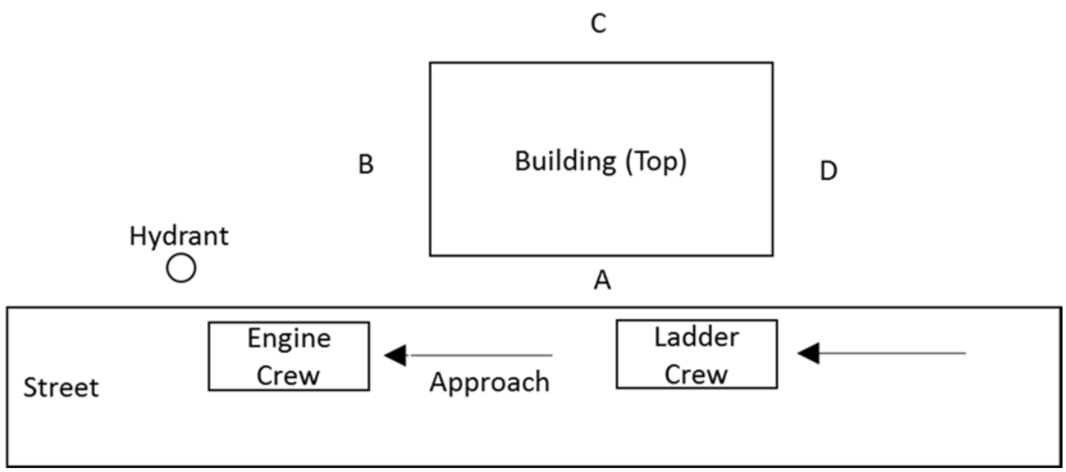


Figure 16: Top-Down Illustration of building face designation during the size-up of an incident. Illustrates the approach of resources during incident command. Street facing side is labeled A or "Address Side" while other faces are labeled B, C, and D in a clockwise fashion. Engine crew sizes up the situation after seeing sides D, A, B and positions itself just past the incident to leave room for the Ladder crew [51].

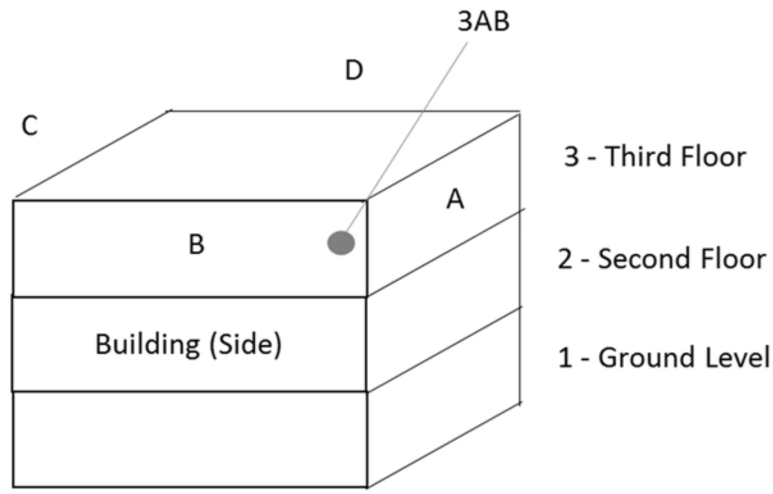


Figure 17: Side Illustration of building face designation during size-up of an incident. Each level is designated by a number or simply referred to as first, second, or third floor. This designation along with the designation of the sides of the building give clarity to communication. The point 3AB serves as an example of how a specific corner of the building can be communicated briefly and efficiently using this method and other similar methods for designation.

The figures illustrate the faces and stories of a building being designated by the convention called for in a Standard Operating Procedure. As can be seen in Figure 17, multi-story buildings can add some complexity to the designation of building areas. Building designation allows for clear consistent communication for resources responding to an incident no matter which department they arrived from, and gives better visibility on where things are happening within the incident as well. For example, if a distress call comes over the radio from a firefighter in 3AB, then it is clear that the firefighter is on the third floor in the corner where faces A and B meet, as illustrated in Figure 17.

From an industrial engineering standpoint, these standards in place provide good process control. During the process of response, the repeated actions called for in this standard allows for approaching and sizing up of an incident relatively the same way each time even if the incident differs. Having seen up to 3/4 of the building or incident in question, the firefighter is more knowledgeable about the current condition, allowing them to make more informed decisions. Furthermore, in the case of a uniquely designed building (L-shaped or multiple subterranean levels) or a fence blocking visibility, then the firefighter will know of areas to be wary of and further investigation can be done [51].

There is also a strong need for stability in keeping track of which firefighters are actually inside buildings fighting fires. Therefore, an Accountability Standard Operating Procedure exists for the tracking of personnel within a structure during a fire. The role of the Accountability Officer is filled by personnel as called for within the Standard Operating Procedure. The accountability officer's role includes the collection and tracking of firefighters' Personal Accountability Safety System (PASS) devices before they enter the building to perform their duties [51]. Afterward, the accountability officer will regularly conduct a Personnel Accountability Report (PAR) over the radio for all personnel being tracked at some time intervals during an incident, complete with a 1 minute warning to let them know the call is coming [51]. If they receive no response from any one individual during the Personal Accountability Report, a Rapid Intervention Team (RIT) stands ready to rescue a possibly incapacitated firefighter [51]. This Standard Operating Procedure illustrates a blending of the federal regulation mandating the use of SCBA equipment and the learned best practices of firefighters understanding that the equipment may be rated for a certain amount of operational time, but may not last exactly that long due to heavy activity when used. Therefore, the intervals in which Personnel Accountability Reports are done is normally timed such that the group is reminded of the time they have already spent working an incident and, at the same time, gives them an awareness of the further capability of their SCBA gear [51].

This method illustrates a desire by users of the Incident Command System to manage and maintain visibility of their responders, while also being able to visualize abnormal conditions. This type of standard is reminiscent of the duties performed by Team Leaders in a Lean system who track various Key Performance Indicators as well as monitoring the work being done to maintain an awareness of the current condition experienced by the frontline production Team Members.

3.1 Problem Solving

The ability to resolve abnormalities based on current factual cues from the system is important in the overall landscape of continuous improvement. In a production environment, even attempting to define a problem can be a daunting task if one is using old data or searching through a large batch of products to find the cause of defects [52]. Therefore, real time detection of defects and occurrences is important, and these events should be broken down, categorized, and visualized clearly for prioritization of a problem which can be resolved to positively affect progress towards the company’s targets and goals. The following sections are dedicated to problem solving of abnormalities and the ability to find solutions that prevent the problem from recurring.

3.1.1 Systematic Problem Solving

Figure 18 depicts the 8 step problem solving process found in Lean manufacturing alongside the Incident Command System problem solving method with its 5 steps as proposed by IS-241b from the Emergency Management Institute’s training documents

[20]. The Incident Command System's process for solving problems seems to share the same foundation of the Plan-Do-Check-Act learning cycle introduced to Japanese industry by Deming. Therefore, both processes show each step aligning to an aspect of the Plan-Do-Check-Act (illustrated P, D, C, or A) process. Differences between the two methods appear in the incompleteness of the Plan-Do-Check-Act cycle in the Incident Command System, which indicates the system lacks the drive for standardizing successful results. A difference also appears in one key aspect promoted by Lean problem solving, the focus on root cause analysis to reduce problem recurrence.

It can be seen in the steps illustrated by the figure that a high emphasis is placed on planning within both problem solving methods during the initial stage of investigation to better understand a problem and develop effective solutions. Furthermore, both of the methods are cyclical, as monitoring the situation or process being addressed ties back to the first step of identifying or clarifying the next problem to purpose.

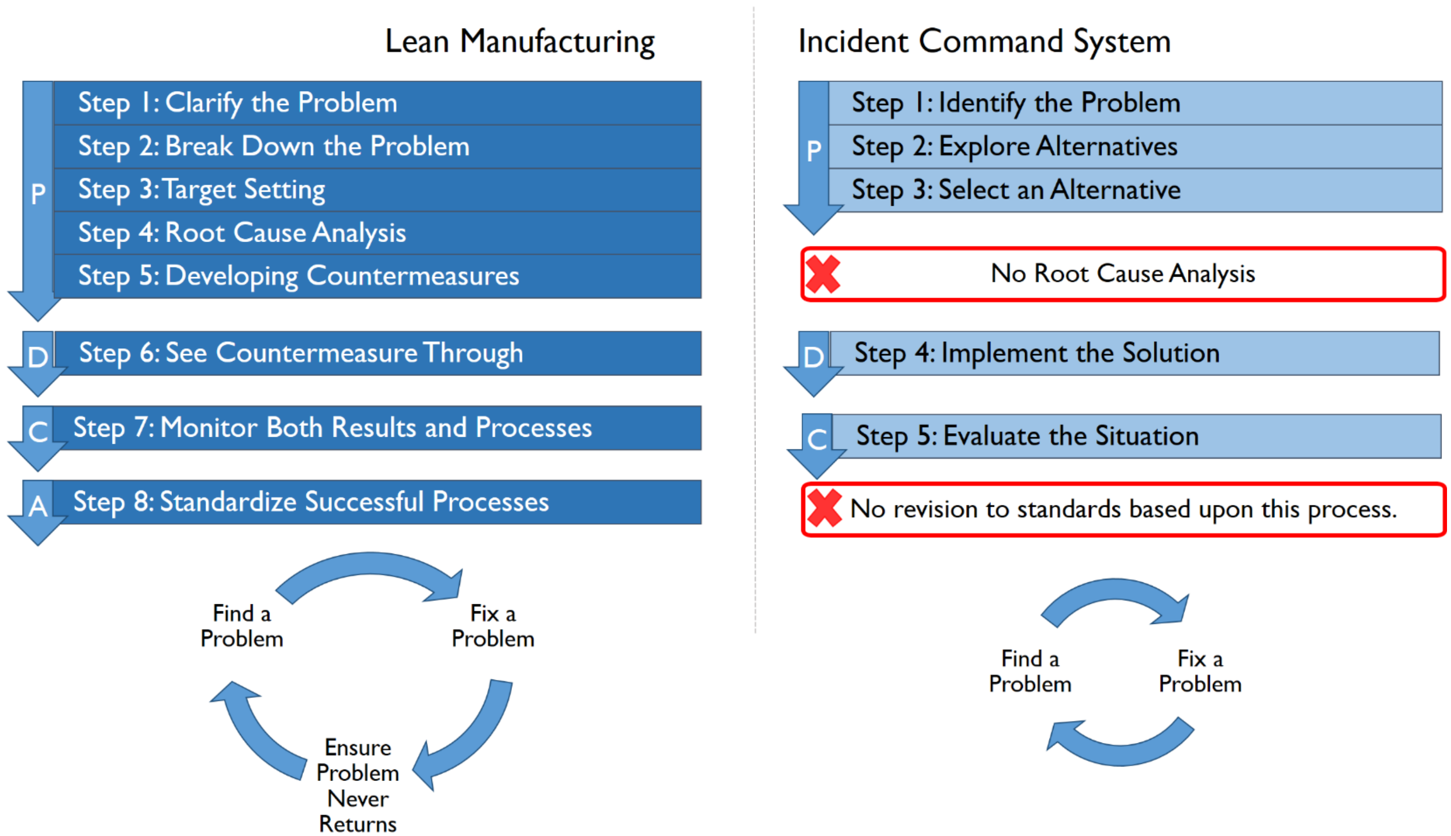


Figure 18: Comparison of Problem Solving Methods used in Lean manufacturing (Left) [28] *and the Incident Command System (Right)* [20]*. The eight-step problem solving method used systematically within Lean organizations emphasizes root cause analysis and standardization of successful implementations* [28]*. This cycle not only encourages the system to find a problem and fix a problem, but helps ensure that the problem never returns. The five-step problem solving method discussed in IS-241b training documents does not emphasize root cause analysis or standardization of successful results* [20]*. This indicates that when the system finds a problem and fixes it, that it cannot be ensured that the problem will never return.*

The Incident Command System's problem solving method is illustrated on the right side of Figure 18. Due to its usage in high stress, high urgency environments, the method promotes various supporting materials in the form of questionnaires or checklists that guide the user towards clarifying, breaking down, and setting goals for problems quickly during an incident. The questionnaire associated with the first step provokes the user to think critically about how to identify, define, and analyze the problem [20]. Step 2 encourages brainstorming, surveys, and discussion groups; this step is supported by a list of questions one should ask themselves regarding various alternatives: constraints, appropriateness, adequacy, effectiveness, efficiency, and side effects [20].

The development of countermeasures follows in the third step with an exercise of listing out all alternatives and writing their degree of limitation in terms of political, safety, financial, environmental, ethical, and other factors [20]. Once a countermeasure is decided on, a 9 point checklist is used in Step 4 to fully describe the solution by outlining targets, methods, resources, timeframe, and who is responsible [20]. Finally, the fifth step involves monitoring progress to evaluate the results and is accompanied by a 6 point checklist to assist with this task [20]. Refer to Appendix B for the complete job aid used for this problem solving model containing all checklists and supplemental items.

The steps of the Lean manufacturing problem solving process is illustrated to the left side of Figure 18, and follows the Plan-Do-Check-Act cycle adamantly. The first three steps of the Lean manufacturing process have the same goal as the Incident Command System's first two steps, but the planning phase continues into a fourth step where root cause analysis is done.

Properly breaking down the problem in step 2 along with performing root cause analysis of step 4 are well-known struggle points within the 8 step process [28] [53]. This is partly due to a learned tendency to commit to a solution for a problem without deeply searching for the cause [28] [53]. Step 2 requires starting with a broad perspective of an issue and narrowing down all contributions to find a unique problem to prioritize based on severity or frequency of occurrence. If the problem breakdown is not done thoroughly, the rest of the process is adversely affected until the breakdown is revisited and corrected to go as deeply as necessary.

Analyzing the root cause is typically achieved in step 4 by asking “Why” multiple times in relation to the target. The target is set in step 3 and based on the prioritized problem found in step 2. This process drills even deeper to find the true cause of a problem for elimination. Following the process thoroughly promotes the cycle illustrated in the figure of finding and fixing a problem, where the addition of tracing it back to a root cause and standardizing successful results will provide the opportunity to prevent recurrence [28].

Towards the end of the planning phase of Plan-Do-Check-Act problem solving, both systems move forward to develop, implement, and monitor countermeasures. The absence of thorough root cause analysis in either method will lead to multiple iterations of countermeasures based on trial and error until something works, where the true cause of the problem may still be unresolved. Also important in the closing stages of problem solving is the standardization of successful results. This step serves to communicate the problem as well as the changes associated to those who will be affected by it, or those who can benefit from the knowledge. This sharing of information is important for maintaining the level of organizational learning desired in any system.

Unsuccessful applications of Lean manufacturing typically result from an over-emphasis on immediate improvement which often ignores the importance of thorough problem solving and well maintained standardization [54]. The Incident Command System's training documents do not explicitly state standardization and incorporation as part of the current best method, but these aspects are clearly required for continuous improvement. Furthermore, resolving issues without finding the root cause will risk in recurrence of problems. The Incident Command System's process shown in Figure 18 encourages finding and fixing problems, but will not prevent recurrence unless problems are traced back to the root cause and the results are incorporated into the standard procedures of the Incident Command System.

3.1.2 Problem Recurrence and Continuous Improvement

Donahue and Tuohy [55] recognized recurrence of problems in their analysis of learning capabilities within the Incident Command System. After careful review of post incident reports, they concluded the need for the drive and ability to solve problems permanently rather than suffer them repeatedly [55]. Moynihan [56] further explored the concepts of organizational learning in the Incident Command System with regards to learning that takes place during the management of an incident (intra-crisis learning) and learning that takes place as reflection outside of an incident (inter-crisis learning). Moynihan also noted that the development and revision process taking place during the learning that occurs via reflection would effectively minimize the amount of learning required during incidents [57].

The Incident Command System's use of questionnaires, checklists, and other materials are intended to direct problem solving while streamlining the decision making process. Users of the 5 Step Problem solving process shown on the right of Figure 18 benefit from a fairly swift process to determine countermeasures during the midst of an incident. However, it's unknown to the author whether this 5 step method is also used during reflection of an incident to develop countermeasures for systematic problems or general instability within repeatable processes. The addition of root cause analysis and standardization of successful results during reflection of an incident could provide an opportunity for deeper understanding of what causes various recurring struggle points. This type of deep investigation promotes an intuitive understanding of the processes in question. In turn, this level of understanding increases the effectiveness of the documents used for stability such as Lean Standardized Work documents or Firefighter Standard Operating Procedures encouraging continuous improvement within the systems.

For a wildland fire environment, instabilities can be found even between the groups of responders who work together to manage incidents. Incident Management Teams could be dispatched from one wildland fire to the next to work with an entirely different structure and circumvent the reflection process for an incident entirely [13]. The most stable roles within wildland environments would be those that develop the Resource Management Plans and Fire Management Plans. Those who develop these plans typically have authority over incidents that occur in their area [13] and should have access to information gathered during incident management. This information could be processed through the 8 step method to discover and eliminate root cause for revision and further development of Resource Management Plans, Fire Management Plans, and other standards to promote continuous improvement.

The importance of problems in any environment arises from the fact that they will occur inevitably. The key approach used by Lean manufacturing methods is to develop a system capable of communicating those problems or gaps in real time in order to use them as an opportunity for improvement. This hinges on adherence to the Plan-Do-Check-Act learning cycle and the system's ability to retain or spread information to prevent problem recurrence.

The Lean approach to obtaining timely operational feedback for improvement is based on system stability through the aforementioned standards for roles, responsibilities, and methods. This level of definition within the system increases as these component are improved through waste reduction and reduction of general confusion within the system. A general illustration of the Continuous Improvement process is shown in Figure 19, where improvement is shown as steps upward. These continuous improvement activities not only benefits systems components but also work towards providing better definition for the system itself.

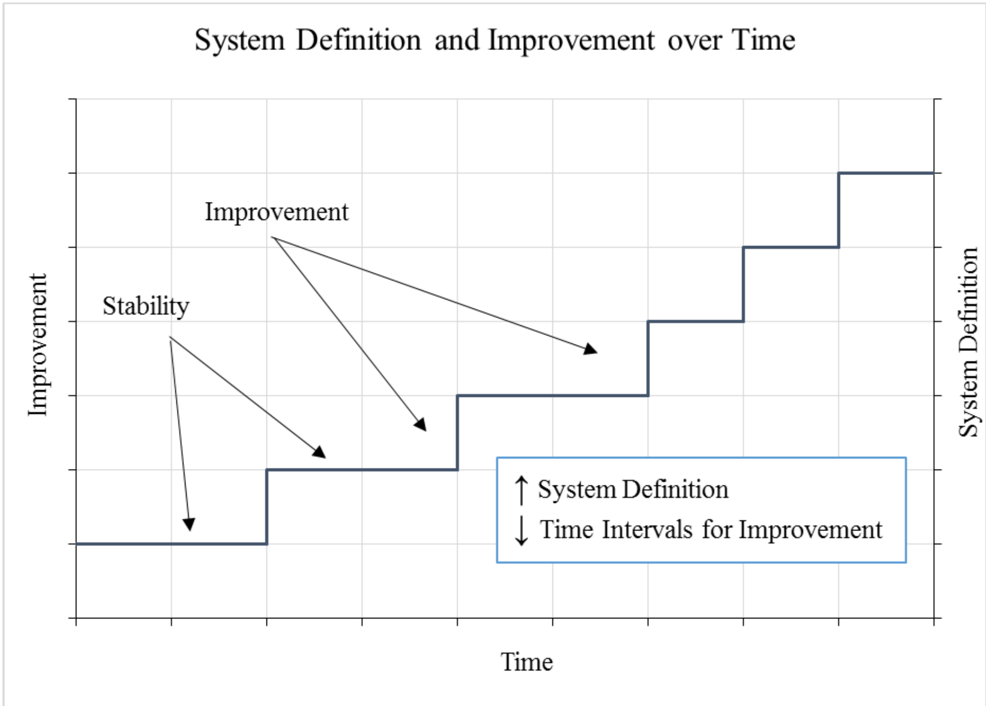


Figure 19: Continuous Improvement and stability in a system promote a decrease in the time required for further improvements resulting from better definition of the system.

The clarity gained from improvements made in a stable and well-defined system gives rise to the opportunity for more frequent continuous improvement activities because of the ability to distinguish abnormal and normal conditions within the system. This is only possible if the knowledge gained from improvement activities is retained and understood throughout the organization.

Figure 20 demonstrates the cycle of continuously evaluating how effectively the Incident Command System responds through each iteration of addressing incidents (Fires 1,2,3,…,n). The Incident Command System then uses this data from each incident to improve the efficiency of response and goes on to repeat the process.

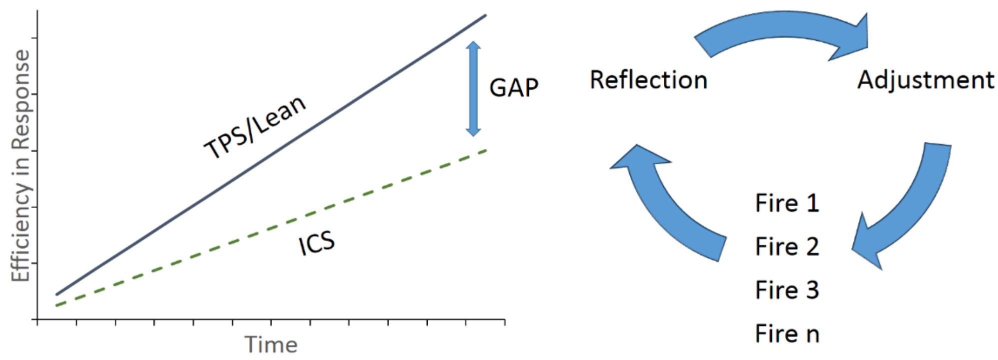


Figure 20: Anticipated incremental improvements in TPS/Lean organizations versus improvements in the Incident Command System. Based on Maginnis [41].

Figure 20 also illustrates an anticipated gap that occurs between systems applying TPS/Lean methods and the Incident Command System without root cause analysis and strict adherence to standardizing successful results [41].

3.1.3 Gap Analysis for Determining Needs

Gaps within the fire services are also explored by the National Fire Protection Association through the "Needs Assessments for the U.S. Fire Services" report. The Needs Assessment is published every 5 years since 2001 and composed with data from the prior year. Each report provides comparisons to previous needs assessments. For example, the 2011 assessment is compared with results of both reports published in 2001 and 2006 to illustrate improvements as well as remaining gaps to show needs of fire services [4]. The intention of this report is to direct grant money to improve fire services by comparing survey-based statistics to regulatory requirements within the following 6 core areas: personnel and capabilities, facilities and apparatus, personal protective equipment, fire prevention and code enforcement, ability to handle unusually challenging incidents, and communications/new technology [4].

The categories in the report are separated into different sections to reflect needs based on size of population protected. This stratification was shown necessary in the report due to the trend that fire services protecting smaller communities generally display greater needs since there are more departments covering smaller communities to be surveyed [4]. Furthermore, the report is broken down to provide fact sheets and statistical reports for each state in the United States [58]. Appendix C contains a portion of the United States report, and the fact sheet for Kentucky from 2011 can be found in Appendix D.

These reports discuss general improvements across the board for the United States as a whole [4], and some improvement in certain areas for the state of Kentucky [58]. The percentage of estimated need for Self Contained Breathing Apparatus to outfit all firefighters in departments across the nation, as well as in Kentucky, are illustrated in Figure 21. This contribution towards a clear picture of fire services along with an illustration of needs is admirable. This information is also key in preventing fire services from suffering the consequences of outdated equipment, facilities, or a lack of written agreements with coordinating agencies.

Figure 21 illustrates a particular result of the report regarding Self Contained Breathing Apparatus needs for fire services in 2011. The figure is interpreted to read "52% of the all fire departments cannot equip firefighters on a shift with self contained breathing apparatus, down from 70% in 2001, and 60% in 2005" [4].

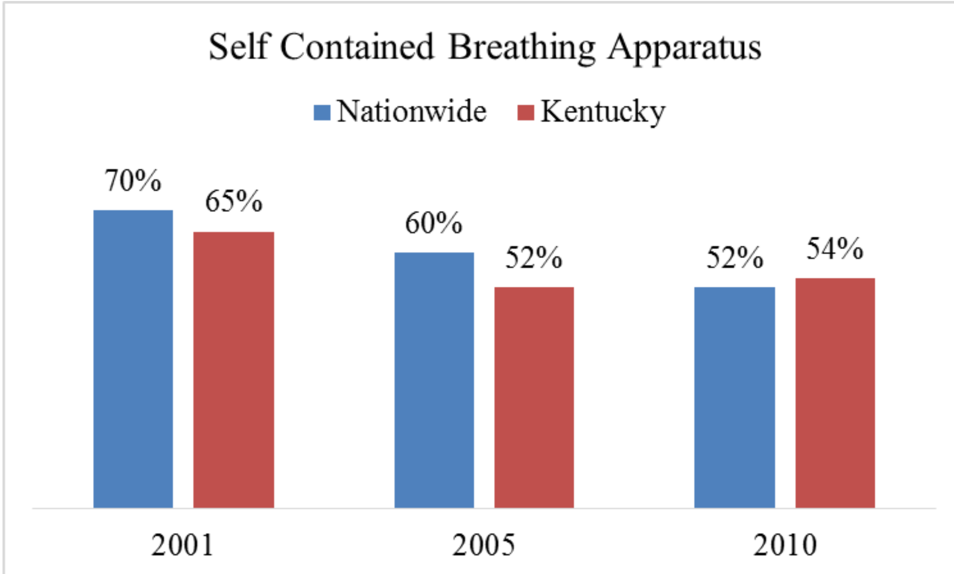


Figure 21: Self Contained Breathing Apparatus needs in the United States fire services (blue) [4] *and Kentucky fire services (red)* [58].

As encouraging as this communication of needs may be for stimulating improvements, these statistics don't seem to drill down past illustrating general gaps. It would be interesting to see needs based directly on processes performed by fire services in the United States. When looking at needs deeply from this process perspective, it allows for the development of performance indicators that would affect these statistics in real time. The needs would then be communicated and monitored at multiple levels within the system allowing for maintenance of the current, clear information. Figure 22 illustrates a strictly theoretical example of Key Performance Indicators that could be tracked to communicate the effects of Self Contained Breathing Apparatus equipment upon three categories of performance within an organization.

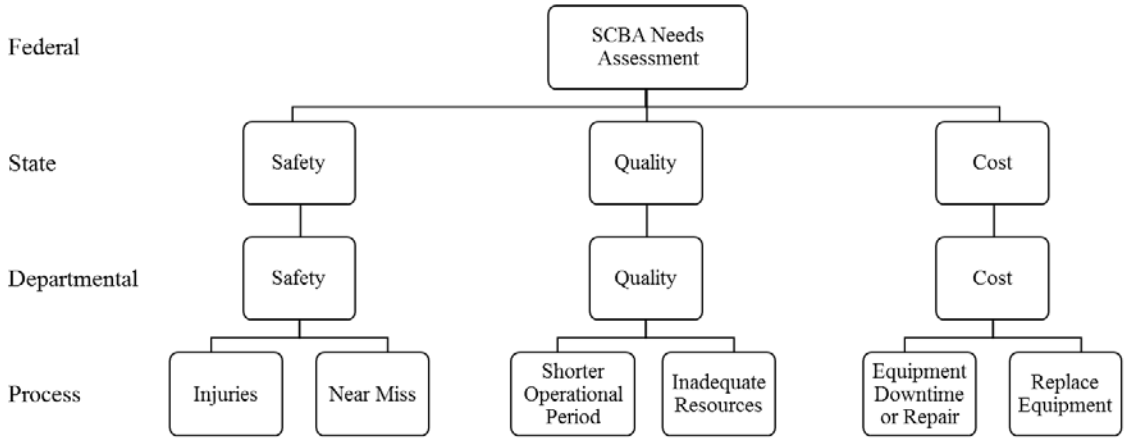


Figure 22: Theoretical hierarchy of Key Performance Indicators for Fire Services.

The three performance indicators shown in Figure 22, Safety, Quality, and Cost are based on information tracked at the process and collaborated at the departmental level. This information would then be communicated to the state level to be combined with data from other departments to be shared at the federal level as a performance measure that would indicate needs. The performance indicators displayed at the departmental level would be regularly updated through documenting process abnormalities, tracking response time, etc.

This effort would also encourage some level of activity at the departmental level for improvement. Going deeper into these categories to better understand the reasoning behind gaps may also provide insight into methods of reducing them without monetary contributions as well.

CHAPTER 4: CONCLUSION

4.0 Conclusions

The robust learning cycle present within a successful Lean manufacturing environment hinges on a Plan-Do-Check-Act process which facilitates continuous improvement when followed rigorously. This is due to a deeper level of learning achieved from investigations of root cause to eliminate problems [59]. In addition, Lean systems retain and spread information regarding improvements throughout the system by continual revision of standards and effective communication in response to problem solving successes. This also serves to drive the system towards future efforts for continuous improvement as goals have been effectively raised and set. The Incident Command System attempts to follow the Plan-Do-Check-Act cycle, but literature indicates that the system struggles with problem recurrence; therefore application of root cause analysis may be able to significantly contribute to the effectiveness of future emergency responses. Furthermore, the Incident Command System's training documents regarding problem solving do not guide the user to post-problem solving efforts intended to retain and spread knowledge throughout the system. This highlights an area where loss of valuable incident based knowledge would occur, which could be remedied through more diligent revision of standards.

The use of statistics to illustrate the needs of fire services within the Unites States provides an opportunity to reduce those needs by sharing them. However, some exploration of these needs at the process level would be useful in providing a better overall picture of the system. The monitoring and maintenance of these performance indicators at various levels of the fire services would also facilitate continuous improvement. This is because problem identification and prioritization are essentially streamlined through access to the most current information. Finally, the application of these key performance indicators in real time would provide an opportunity for more frequent statistical analysis and reporting.

After analyzing the Incident Command System and Lean manufacturing to form an overall understanding of both systems, it seems readily apparent that the application of Lean methods would be extremely promising. Similarities between the two systems indicate possibility for success, while the differences only imply opportunity.

4.1 Future Considerations

For the duration of this study, it was intended to understand the Incident Command System and Lean manufacturing organizations better in order to consider the Incident Command System from a Lean manufacturing perspective. This was done in order to assess whether or not Lean could be applied to the Incident Command System. Because of the encouraging similarities between the two systems discussed in this thesis, future studies could be more focused towards application of the various tools sought out by manufacturing professionals around the world. Some primary tools associated with Lean manufacturing that could be implemented into any department to aid in preparation for incident management would be 5S (Sort, Straighten, Shine, Standardize, and Sustain) [60], Waste Elimination of the 7 critical wastes (Waiting, Overproduction, Rework, Motion, Processing, Inventory, and Transportation) [60], and Visual Management of results of these efforts.

These principles are fairly straightforward, but require diligence to maintain results and drive to improve further. Implementation of these tools would be most successful within a “model area” of an organization rather than being deployed across the entire framework [28]. This approach allows for better support towards the model area during implementation, and results from this implementation can be used to lead by example in order to spread throughout the organization. The development of a model area also results in experienced members of the organization who understand the struggles of implementing the new approach and can serve in a support function to other areas who may be working towards implementing Lean principles as well.

Due to the various gaps discovered between these two systems. Future work could serve to investigate the statistics published by the National Fire Protection Association, as well as other entities, in order to better understand them. This would require an effort by the investigator to track down comparisons of various levels of needs (expressions of no need, some need, and critical need) discussed in the reports, discover what that need physically looks like, and then compare and analyze the related effects of this need realized at the fire departments level among various other perspectives. This could culminate in a quantifiable indication of what is occurring at any one department directly affecting the need expressed.

Furthermore, research into the development of Standard Operating Procedures will need to be done. It would be particularly interesting to see direct comparison between the production maintenance aspects of manufacturing and the Standard Operating Procedures used within the fire services. Further, in this effort the researcher would gain a basic understanding of how Standard Operating Procedures are developed, and then assess the revision of these documents. Most importantly, the number of revisions along with the quality of revisions would give a good indication of how well the system retains knowledge gained by incidents. This would also include assessing the amount of rework done with revising a Standard Operating Procedure.

Critical future research is required as relates to the problem solving method used within the fire services. It is of interest whether current or proposed methods are used during an incident versus different methods that may be used after an incident. It may take a great deal of effort to differentiate problem solving towards addressing an incident to meet incident goals and the problem solving methods used to resolve systemic abnormalities. Furthermore, some indication of the systematic utilization of the 5 step problem solving method could be given through survey or consensus and compilation of the results. However, the rewarding results of these efforts would be an idea of how coordinated the problem solving approach is within the realm of fire management. Systematically solving problems reduces the amount of in depth explanation required for developed solutions because all personnel will “speak the same language” as far as the discussion of their methods and line of thinking towards results.

Finally, many factors are understood to impact the use and effectiveness of the Incident Command System regardless of system design itself. Moynihan [56] stated that barriers to learning during a crisis may result from limited time, political consequence, and weak working relationships between responders. As well, a recent comprehensive literature review published by Jensen and Waugh [61] noted various factors regarding the application of the Incident Command System’s procedures within various other emergency response areas. In order to improve the system overall, it is important to maintain continuous improvement efforts within areas that do use the Incident Command System regularly, such as the firefighting community. These efforts would result in a well defined area of the system that demonstrates efficiency and effectiveness to lead by example and encourage further integration as a unified response community.

APPENDICES

Appendix A: The Planning Process (8 Pages)

Planning Process (page 1 of 8)

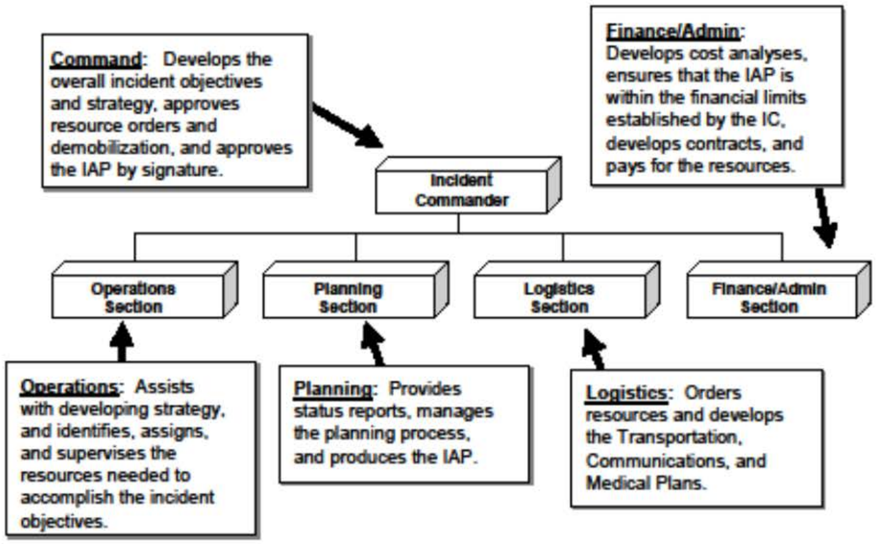
It was recognized early in the development of the ICS that the critical factor of adequate planning for incident operations was often overlooked or not given enough emphasis. This resulted in poor use of resources, inappropriate strategies and tactics, safety problems, higher incident costs, and lower effectiveness.

Those involved in the original ICS development felt that there was a need to develop a simple but thorough process for planning that could be utilized for both smaller, short-term incidents and events, and for longer, more complex incident planning. The planning process may begin with the scheduling of a planned event, the identification of a credible threat, or the initial response to an actual or impending event. The process continues with the implementation of the formalized steps and staffing required to develop a written Incident Action Plan (IAP).

The primary phases of the planning process are essentially the same for the Incident Commander who develops the initial plan, for the Incident Commander and Operations Section Chief revising the initial plan for extended operations, and for the incident management team developing a formal IAP, each following a similar process. During the initial stages of incident management, planners must develop a simple plan that can be communicated through concise verbal briefings. Frequently, this plan must be developed very quickly and with incomplete situation information. As the incident management effort evolves over time, additional lead time, staff, information systems, and technologies enable more detailed planning and cataloging of events and "lessons learned."

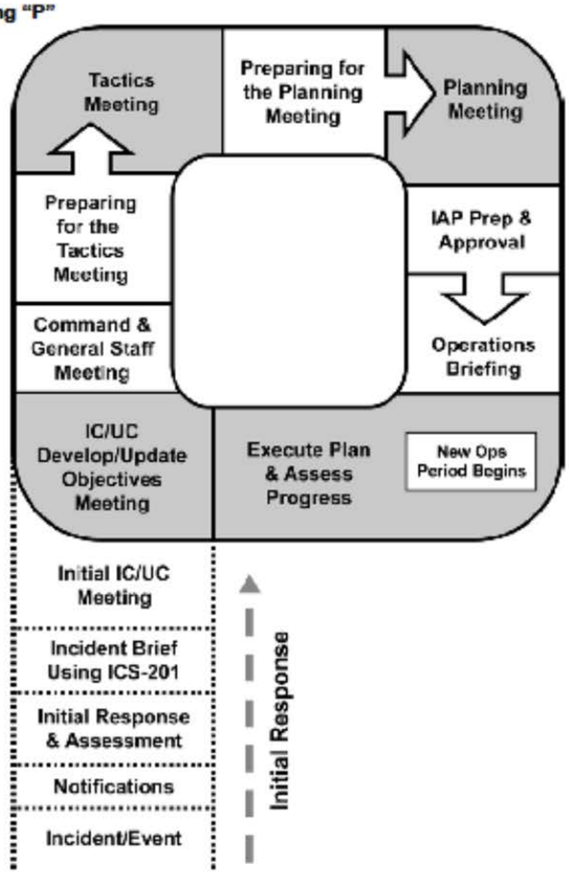
Planning involves:

- Evaluating the situation.
- Developing incident objectives.
- Selecting a strategy.
- Deciding which resources should be used to achieve the objectives in the safest, most efficient and cost-effective manner.



Caption: Organizational chart showing that Command develops the overall incident objectives and strategy, approves resource orders and demobilization, and approves the IAP by signature. Operations assists with developing strategy, and identifies, assigns, and supervises the resources needed to accomplish the incident objectives. Planning provides status reports, manages the planning process, and produces the IAP. Logistics orders resources and develops the Transportation, Communications, and Medical Plans. Finance/Administration develops cost analyses, ensures that the IAP is within the financial limits established by the Incident Commander, develops contracts, and pays for the resources.

The Planning "P"



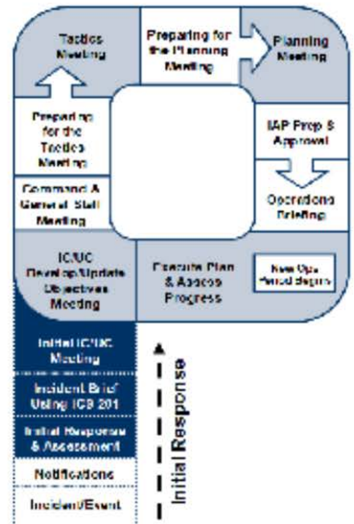
- The Planning "P" is a guide to the process and steps involved in planning for an incident. The leg of the "P" describes the initial response period: Once the incident/event begins, the steps are Notifications, Initial Response & Assessment, Incident Briefing Using ICS 201, and Initial Incident Command (IC)/Unified Command (UC) Meeting.
- At the top of the leg of the "P" is the beginning of the first operational planning period cycle. In this circular sequence, the steps are IC/UC Develop/Update Objectives Meeting, Command and General Staff Meeting, Preparing for the Tactics Meeting, Tactics Meeting, Preparing for the Planning Meeting, Planning Meeting, IAP Prep & Approval, and Operations Briefing.
- At this point a new operational period begins. The next step is Execute Plan & Assess Progress, after which the cycle begins again.

Source: draft NIMS document

Initial Response

Planning begins with a thorough size-up that provides information needed to make initial management decisions.

The ICS Form 201 provides Command Staff with information about the incident situation and the resources allocated to the incident. This form serves as a permanent record of the initial response to the incident and can be used for transfer of command.

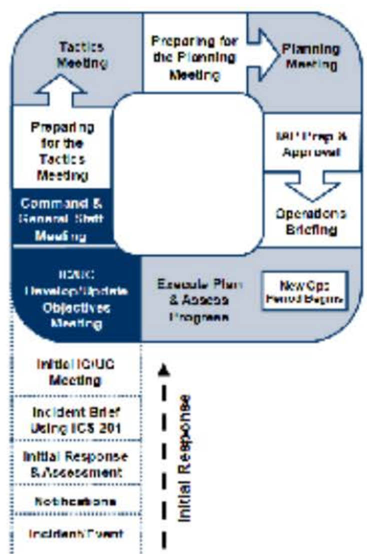


The Start of Each Planning Cycle

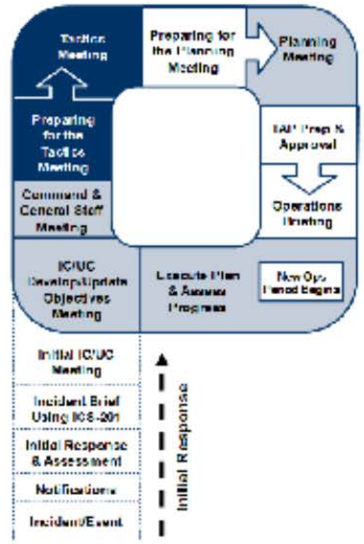
- **IC/UC Objectives Meeting:** The Incident Command/Unified Command establish incident objectives that cover the entire course of the incident. For complex incidents, it may take more than one operational period to accomplish the incident objectives.

  The cyclical planning process is designed to take the overall incident objectives and break them down into tactical assignments for each operational period. It is important that this initial overall approach to establishing incident objectives establish the course of the incident, rather than having incident objectives only address a single operational period.

- **Command and General Staff Meeting:** The Incident Command/Unified Command may meet with the Command and General Staff to gather input or to provide immediate direction that cannot wait until the planning process is completed. This meeting occurs as needed and should be as brief as possible.



Preparing for and Conducting the Tactics Meeting



The purpose of the Tactics Meeting is to review the tactics developed by the Operations Section Chief. This includes the following:

- Determine how the selected strategy will be accomplished in order to achieve the incident objectives.
- Assign resources to implement the tactics.
- Identify methods for monitoring tactics and resources to determine if adjustments are required (e.g., different tactics, different resources, or new strategy).

The Operations Section Chief, Safety Officer, Logistics Section Chief, and Resources Unit Leader attend the Tactics Meeting. The Operations Section Chief leads the Tactics Meeting.

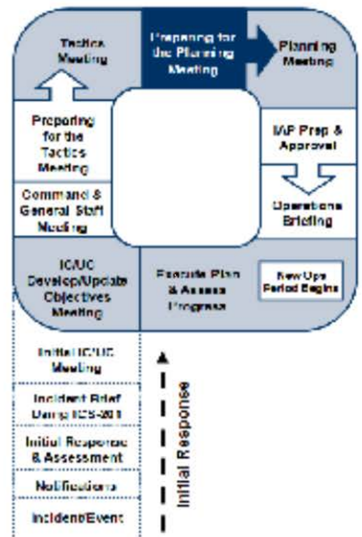
The ICS Forms 215, Operational Planning Worksheet, and 215A, Incident Safety Analysis, are used to document the Tactics Meeting.

Resource assignments will be made for each of the specific work tasks. Resource assignments will consist of the kind, type, and numbers of resources available and needed to achieve the tactical operations desired for the operational period. If the required tactical resources will not be available, then an adjustment should be made to the tactical assignments being planned for the Operational Period. It is very important that tactical resource availability and other needed support be determined prior to spending a great deal of time working on strategies and tactical operations that realistically cannot be achieved.

Preparing for the Planning Meeting

Following the Tactics Meeting, preparations are made for the Planning Meeting, to include the following actions coordinated by the Planning Section:

- Review the ICS Form 215 developed in the Tactics Meeting.
- Review the ICS Form 215A, Incident Safety Analysis (prepared by the Safety Officer), based on the information in the ICS Form 215.
- Assess current operations effectiveness and resource efficiency.
- Gather information to support incident management decisions.

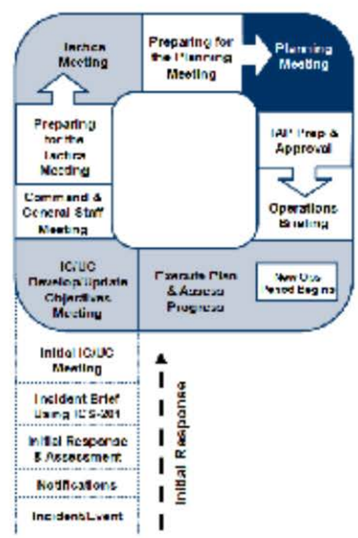


Planning Meeting

The Planning Meeting provides the opportunity for the Command and General Staff to review and validate the operational plan as proposed by the Operations Section Chief. Attendance is required for all Command and General Staff. Additional incident personnel may attend at the request of the Planning Section Chief or the Incident Commander. The Planning Section Chief conducts the Planning Meeting following a fixed agenda.

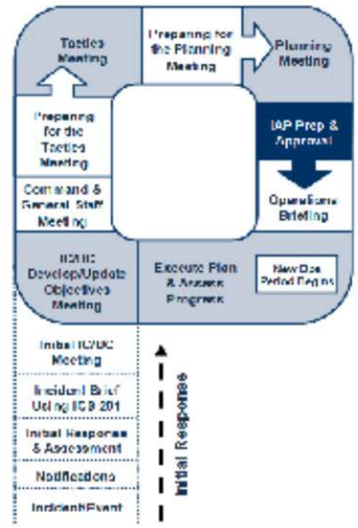
The Operations Section Chief delineates the amount and type of resources he or she will need to accomplish the plan. The Planning Section's "Resources Unit" will have to work with the Logistics Section to accommodate.

At the conclusion of the meeting, the Planning Section Staff will indicate when all elements of the plan and support documents are required to be submitted so the plan can be collated, duplicated, and made ready for the Operational Period Briefing.



IAP Preparation and Approval

The next step in the Incident Action Planning Process is plan preparation and approval. The written plan is comprised of a series of standard forms and supporting documents that convey the Incident Commander's intent and the Operations Section direction for the accomplishment of the plan for that Operational Period.



For simple incidents of short duration, the Incident Action Plan (IAP) will be developed by the Incident Commander and communicated to subordinates in a verbal briefing. The planning associated with this level of complexity does not demand the formal planning meeting process as highlighted above.

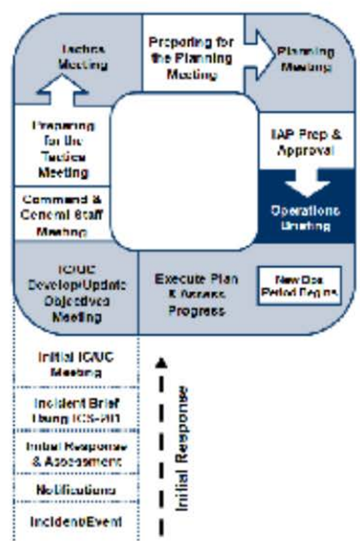
Certain conditions result in the need for the Incident Commander to engage a more formal process. A written IAP should be considered whenever:

- Two or more jurisdictions are involved in the response.
- The incident continues into the next Operational Period.
- A number of ICS organizational elements are activated (typically when General Staff Sections are staffed).
- It is required by agency policy.
- A Hazmat incident is involved (required).

Operations Period Briefing

The Operations Period Briefing may be referred to as the Operational Briefing or the Shift Briefing. This briefing is conducted at the beginning of each Operational Period and presents the Incident Action Plan to supervisors of tactical resources.

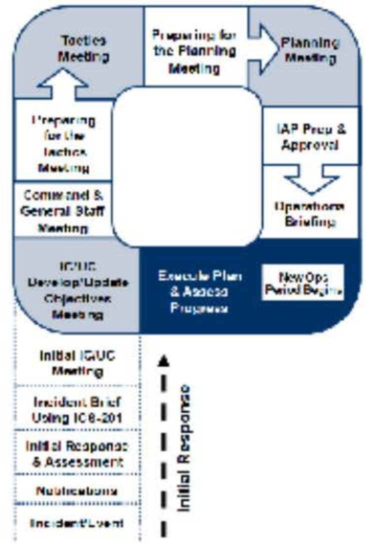
Following the Operations Period Briefing supervisors will meet with their assigned resources for a detailed briefing on their respective assignments.



Execute Plan and Assess Progress

The Operations Section directs the implementation of the plan. The supervisory personnel within the Operations Section are responsible for implementation of the plan for the specific Operational Period.

The plan is evaluated at various stages in its development and implementation. The Operations Section Chief may make the appropriate adjustments during the Operational Period to ensure that the objectives are met and effectiveness is assured.



Appendix B: Job Aid: Problem-Solving Model (11 Pages)

Job Aid: Analytical Approach Problem-Solving Model

This job aid presents a detailed description of the analytical approach process, including checklists and worksheets, and can be printed as desired. This process of making decisions involves five steps:

- Step 1: Identify the problem.
- Step 2: Explore alternatives.
- Step 3: Select an alternative.
- Step 4: Implement the solution.
- Step 5: Evaluate the situation.

Step 1. Identify the Problem

Problem identification is undoubtedly the most important and the most difficult step in the process. All subsequent steps will be based on how you define and assess the problem at hand.

What Is a "Problem"?

A problem is a situation or condition of people or the organization that will exist in the future, and that is considered undesirable by members of the organization.

Problem or Solution?

In carrying out Step 1, you must distinguish between a problem and its solution. The most common error in problem solving is defining problems in terms of their solutions. Sometimes people think that they are articulating problems when actually they are stating a potential solution.

Here's an example: Someone might say, "The problem is that we don't have an EOC." The problem, however, is not that there is no EOC. The problem is really that the emergency management community cannot coordinate communications adequately during the response phase. Establishing an EOC is a solution.

Delineating the Problem Parameters

Identifying the problem also involves analyzing the situation to determine the extent of the problem. Problem parameters include:

- What is happening (and is not happening).
- Who is involved.
- What the stakes are.

The checklist on the following page presents a set of questions that can help you define a problem accurately.

Checklist for Identifying, Defining, and Analyzing Problems

Question	Yes	No
1. Is this a new problem?	☐	☐
2. Is the problem clearly and precisely stated?	☐	☐
3. What assumptions am I making about the problem? (List.) Are they true?	☐	☐
4. What would happen if nothing were done about this problem?		
5. Can the problem be restated in other terms? If yes, how?	☐	☐
6. What data are known that bear on the problem?		

Checklist for Identifying, Defining, and Analyzing Problems (Continued)

Question	Yes	No
7. Is the information accurate?	☐	☐
8. Are there any precedents or rules about other procedures that apply to the problem? If so, what precedents or rules apply?	☐	☐
9. What additional facts are needed to analyze the problem? (List.)		
10. Is it possible to interpret the facts differently? How would that affect the problem's solution?	☐	☐
11. Do I have to make this decision, or does someone else? If this decision is someone else's to make, whose is it?		

Step 2. Explore Alternatives

The second step in the decision-making process is to explore alternative solutions to the problem identified in Step 1. This step really consists of two parts:

- Generating alternatives.
- Evaluating alternatives.

Techniques for Generating Alternatives

- **Brainstorming** can be done individually or in a group. Brainstorming requires an environment in which the participants (individuals or group members) are free to "think out loud." Participants blurt out as many ideas as possible within a specified time period. No evaluation of ideas is permitted so as to encourage the free flow of creative ideas. These ideas are recorded. When the specified time period ends, then evaluation of the ideas begins.
- **Surveys** economically tap the ideas of a large group of respondents. Surveys present respondents with the problem and a series of alternative solutions.
- **Discussion groups** should consist of those who are directly involved in decision making. In generating alternatives, the group members should:
    - Be comprehensive.
    - Avoid initial judgments (as in brainstorming).
    - Focus on the problem, not on the personalities of the people involved in the decision-making process. (But be sensitive to the impact of personalities on the process.)

Criteria for Evaluating Alternatives

After you have generated alternative solutions, you must have some means of evaluating them. The job aid on the following page lists criteria by which you can evaluate alternatives.

Another part of evaluation is identifying contingencies—what could go wrong. Think in terms of Murphy's Law ("If anything can go wrong, it will.") and identify what could get in the way of solving the problem you are facing.

Criteria for Evaluating Alternatives

Step	Questions To Ask
1. Identify Constraints	Do any of the following factors serve as a limitation on this solution? • Technical (limited equipment or technology) • Political (legal restrictions or ordinances) • Economic (cost or capital restrictions) • Social (restrictions imposed by organized groups with special interests) • Human resources (limited ability of relevant people to understand or initiate certain actions) • Time (requirements that a solution be found within a prescribed time period, thereby eliminating consideration of long-range solutions)
2. Determine Appropriateness	Does this solution fit the circumstances?
3. Verify Adequacy	Will this option make enough of a difference to be worth doing?
4. Evaluate Effectiveness	Will this option meet the objective?
5. Evaluate Efficiency	What is the cost/benefit ratio of this option?
6. Determine Side Effects	What are the ramifications of this option?

Step 3. Select an Alternative

The third step in the problem-solving model is to select one of the alternatives explored in Step 2 for implementation. Selecting an alternative is a critical step in the problem-solving process. After you have evaluated each alternative, one should stand out as coming closest to solving the problem with the most advantages and fewest disadvantages.

Implementing the solution may not be easy, however. There may be repercussions, and you should complete a "reality check" to identify and evaluate the possible consequences of implementing the solution. Carefully consider how the solution will be implemented before selecting an alternative.

When selecting an alternative, you will encounter factors that affect your decision making. These factors may include:

- Political factors.
- Safety factors.
- Financial factors.
- Environmental considerations.
- Ethical factors.

Not all of these factors may be readily recognizable. As you examine the situation and apply the problem-solving model, be alert for these potential limits on the solutions that you can implement.

Selecting Alternatives: Best Solutions

Solution:
Limiting Factors:
Political:
Safety:
Financial:
Environmental:
Ethical:
Other:

Solution:
Limiting Factors:
Political:
Safety:
Financial:
Environmental:
Ethical:
Other:

Solution:
Limiting Factors:
Political:
Safety:
Financial:
Environmental:
Ethical:
Other:

If you have more than one clear solution, can any be combined?

Step 4. Implement the Solution

The fourth step involves five subparts as detailed below.

- **Develop an action plan.** Implementation requires a series of steps to:
  - Articulate who has to do what, with what resources, by what time, and toward what goal.
  - Identify who must know about the decision.

  The Action Planning Checklist on the following page will help you to plan the details needed for implementation.

- **Determine objectives.** Objectives are measurable targets that are:
  - Used to monitor progress and establish priorities.
  - Based on analysis of the situation and contingencies.

- **Identify needed resources.** Resources include people, information (data), and things. Ask yourself:
  - What resources do I need?
  - Where will I get them?
  - How long will it take?
  - What can others offer?
  - Are there any special requirements?

- **Build a plan.** Your plan should state:
  - Who
  - Will do what (and with whom)
  - By when
  - Where
  - How

  Remember: Communicate the plan to all parties involved!

- **Implement the plan.** Use the action plan to put the decision in place.

Action Planning Checklist

Use the following questions to help you develop any details needed to plan for implementation of the decision.

Question	Yes	No
1. Will the decision be implemented as it stands or will it have to be modified? ☐ As it stands ☐ With modifications (list)		
2. Does the decision fit the problem and conditions specified earlier?	☐	☐
3. Is this decision still the best option? If no, what has changed?	☐	☐
4. What are the side effects of this decision?		
5. Who is responsible for taking action?		

Action Planning Checklist (Continued)

Question	Yes	No
6. Are the specific targets to be accomplished and the techniques for accomplishing them defined?	☐	☐

If no, what targets and techniques required further definition?

7. What specific activities must take place to implement this decision? In what sequence?

8. What resources will be needed to implement this decision?

9. What is the schedule or timetable for implementation of each step in the action plan?

Step 5. Evaluate the Situation

Evaluation involves two parts:

- **Monitoring progress.** Ask:
  - Has the situation changed?
  - Are more (or fewer) resources required?
  - Is a different alternative solution required?

  Monitoring the success and results of a decision is an ongoing process that is critical to fine-tuning a course of action.

- **Evaluating the results.** Use the following checklist to help you evaluate the decision.

Evaluation Checklist

Use the questions below as a guide for evaluating the results of your decision making.

Question	Yes	No
1. How will you know if the proposed decision has worked?		
Is it measurable? If yes, how?	☐	☐
2. Does the decision and action plan make use of existing channels of communication to generate feedback?	☐	☐
3. Will the feedback test the effectiveness of the decision?	☐	☐
4. Will the feedback be sufficient to reflect changing circumstances and conditions that might occasion the need to modify the plan?	☐	☐
5. Is the solution achieving its purpose?	☐	☐
6. Is timely information generated so that it can be supplied to operational, administrative, and policy units in the jurisdiction?	☐	☐

Appendix C: Overall United States Needs Assessment Data (4 Pages)

Figure 3-4. Percent of Departments Without a Reserve of At Least 10% of In-Service Portable Radios by Size of Community, for Three Studies

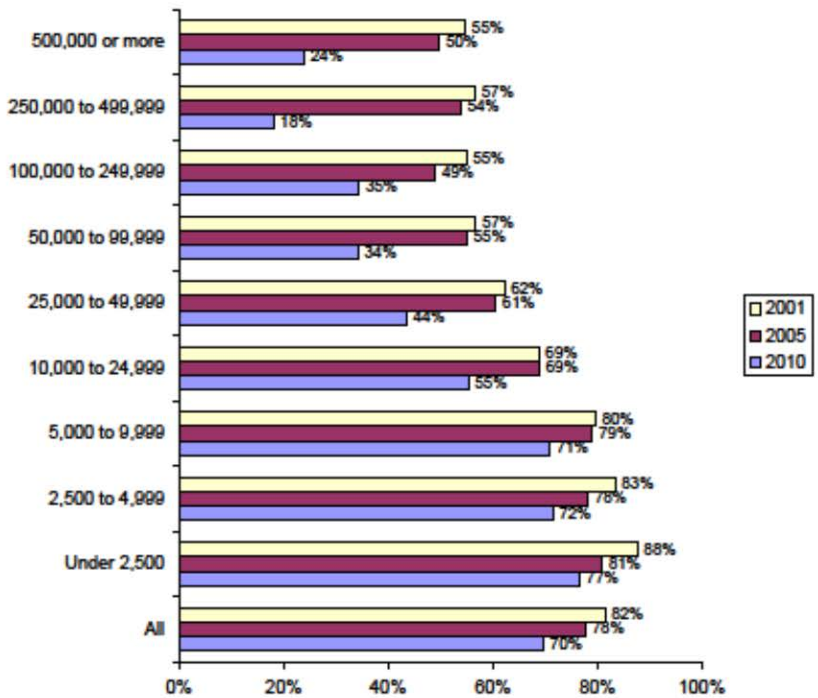


Figure 3-4 shows the shift across the years in percentages of departments where not all radios are intrinsically safe in an explosive atmosphere.

There has been some overall progress, especially for larger communities.

Self-Contained Breathing Apparatus (SCBA)

Overall, half (52%) of departments cannot equip all firefighters on a shift with their own self-contained breathing apparatus (SCBA). (See Table 3-5.) Table 3-6 estimates what fraction of SCBA units are at least 10 years old. Table 3-B shows both measures of need together.

77

Table 3-B. Departments Where Not All Firefighters on a Shift Have SCBA and Where At Least Some SCBA Units Are At Least 10 Years Old, by Size of Community (Q. 28a, 28b)

Population Protected	Departments Where Not All Firefighters on a Shift Are Equipped With SCBA	Departments Where At Least Some SCBA Units Are At Least 10 Years Old
500,000 or more	0%	40%
250,000 to 499,999	0%	54%
100,000 to 249,999	2%	33%
50,000 to 99,999	1%	41%
25,000 to 49,999	8%	41%
10,000 to 24,999	16%	45%
5,000 to 9,999	36%	50%
2,500 to 4,999	56%	53%
Under 2,500	70%	61%
Total	52%	55%

The above projections are based on 4,627 departments reporting on Question 28a and 4,582 reporting on Question 28b. "Don't Know" responses to Question 28b are proportionally allocated. See Tables 3-5 to 3-6.

Q. 28a: How many emergency responders on-duty on a single shift can be equipped with self-contained breathing apparatus (SCBA)? All, Most, Some, None
Q. 28b: How many of your SCBA are 10 years old or older? All, Most, Some, None

Figure 3-5 shows how the percentages of departments where not all firefighters on a shift are equipped with SCBA have changed over the years. There has been considerable progress, with the overall percentage of departments in need declining from 70% in 2001 to 60% in 2005 and 52% in 2010. That is about 5,000 departments moving from need to not-need between the first and third surveys. Progress has occurred across the board.

This shift may in part reflect the influence of the equipment portions of the U.S. Fire Administration grants. For grants during 2001-2004, grants to purchase firefighting or personal protective equipment accounted for an estimated 71% of total grants and 64% of total dollars granted for all grant recipient departments.[9] These percents applied across all population protected groups, except for the smallest communities, where the percents of dollars granted used to purchase apparatus were by far the highest.

Overall, half of departments (55%) reported that some of their SCBA equipment was at least 10 years old. (See Table 3-6.)

[9] *Matching Assistance to Firefighters Grants to the Reported Needs of the U.S. Fire Service*, FA-304, U.S. Fire Administration, October 2006.

Figure 3-5. Percent of Departments Where Not All Firefighters on a Shift Are Equipped With SCBA by Size of Community, for Three Studies

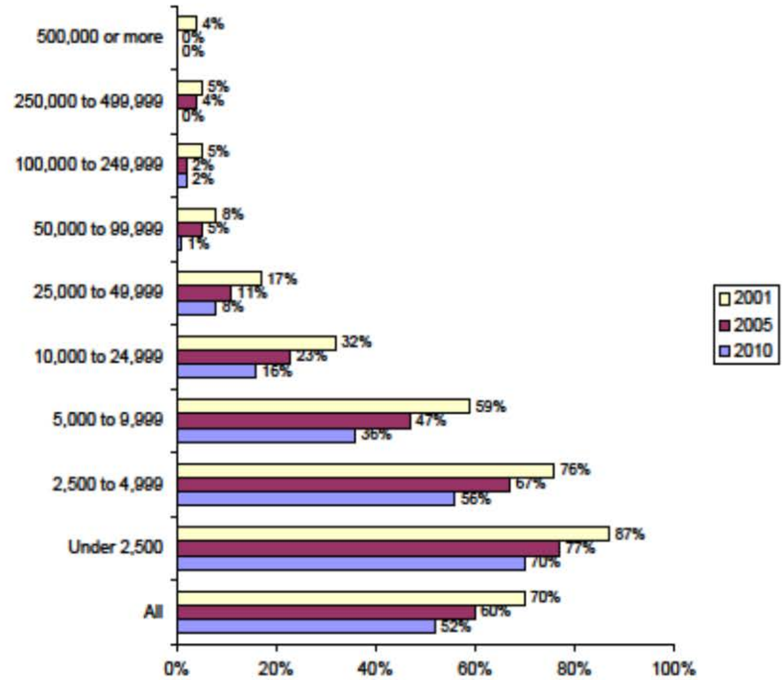


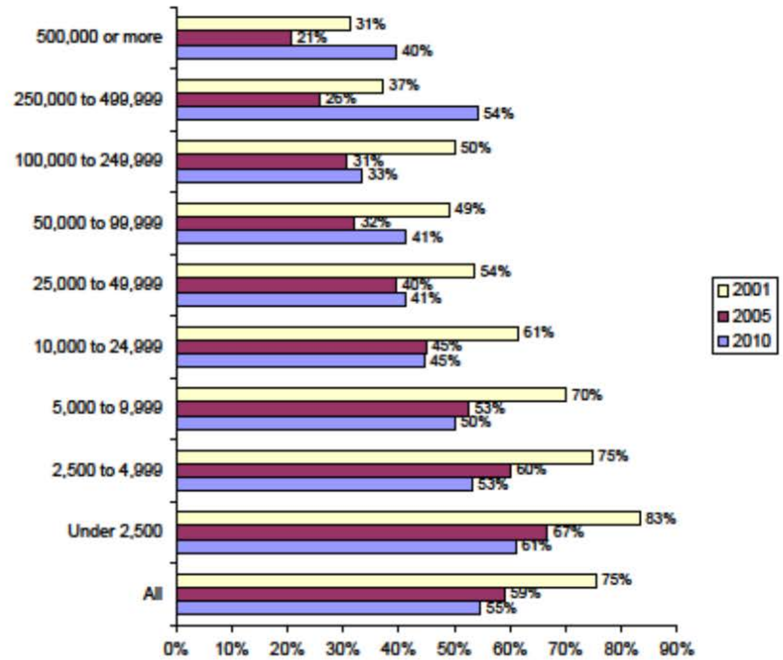
Figure 3-6 shows how the percentages of departments have changed over the years with respect to having no SCBA that is at least 10 years old.

There has been considerable progress overall, dominated by progress in the smaller communities, under 25,000 population.

For communities between 25,000 and 249,999, there has been net progress from first survey to third survey but not from second survey to third survey.

For communities with at least 250,000 population, there was progress from the first to the second survey, but it was more than reversed by increases in estimated need going from the second to the third survey.

Figure 3-6. Percent of Departments Where Some SCBA Is At Least 10 Years Old by Size of Community, for Three Studies



It may be that smaller communities are less likely to have old SCBA, because smaller communities tended to be later in obtaining sufficient SCBA to begin with.

Personal Alert Safety System (PASS) Devices

Overall, two out of five (39%) departments cannot equip all emergency responders on a shift with their own personal alert safety system devices (PASS). (See Table 3-7.) Table 3-C shows level of need by size of community.

Appendix D: Kentucky Needs Assessment Fact Sheet (2 Pages)

NFPA
One-Stop Data Shop
Fire Analysis and Research Division
One Batterymarch Park, Quincy, MA 02169
Email: osds@nfpa.org
www.nfpa.org

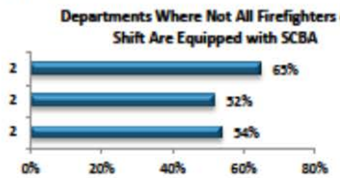
Fact Sheet
Kentucky Fire Service Needs Assessment

There has been substantial progress in reducing many fire department needs, although more remains to be done.

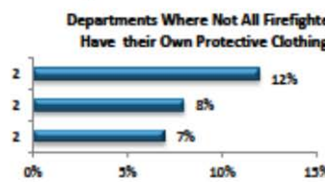
Protective Equipment and Clothing

The 2010 percentage of Kentucky departments **without enough equipment to equip all personnel** (or all personnel on a shift, as appropriate) was:

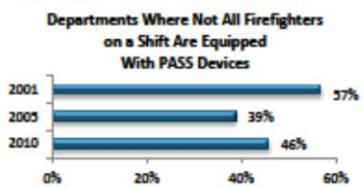
- 54% for **self-contained breathing apparatus** (SCBA), compared to 65% in 2001 and 52% in 2005;



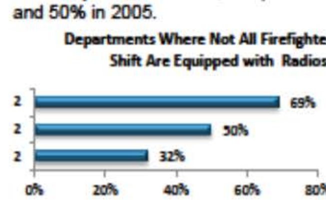
- 7% for **personal protective clothing**, compared to 12% in 2001 and 8% in 2005; and



- 46% for **personal alert safety system devices** (PASS), compared to 57% in 2001 and 39% in 2005;



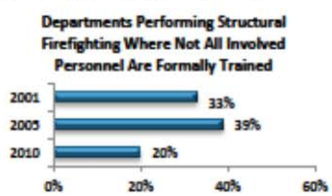
- 32% for **portable radios**, compared to 69% in 2001 and 50% in 2005.



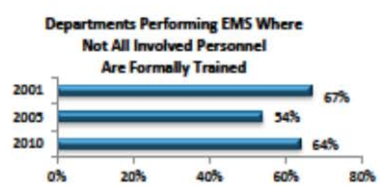
Training

In many fire departments, **not all involved personnel have been formally trained** in their emergency response duties. The 2010 percentage of Kentucky departments in which not all involved personnel have been formally trained was:

- 20% for **structural firefighting**, compared to 33% in 2001 and 39% in 2005; and



- 64% for **emergency medical service** (EMS), compared to 67% in 2001 and 54% in 2005.

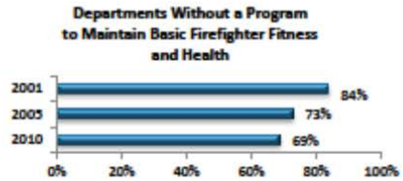


Source: Third Needs Assessment of the U.S. Fire Service, KY, NFPA, Fire Analysis and Research, Quincy, MA. October 2011

Fitness and Health

In many fire departments, **there is no program to maintain basic firefighter fitness and health.** The 2010 percentage of Kentucky departments with no such program was:

- 69%, compared to 84% in 2001 and 73% in 2005.



Unusually Challenging Incidents

There has been little or no progress in increasing the ability of fire departments to handle various **unusually challenging incidents** with local trained personnel and specialized equipment alone:

- Provide technical rescue and EMS at a **structural collapse** involving 50 occupants; and
- Provide hazardous material response and EMS at an incident involving **chemical or biological agents** and with 10 injuries.
- **Wildland/urban interface (WUI) fire** affecting 500 acres; and
- Mitigation of a **major developing flood**.

However, there has been progress in the percentage of departments having written agreements for working with others. The 2010 percentage of Kentucky departments with *no* such written agreement was:

- 59% for structural collapse, compared to 67% in 2001 and 53% in 2005;
- 55% for chemical or biological incidents, compared to 73% in 2001 and 54% in 2005;
- 57% for wildland/urban interface fires, compared to 69% in 2001 and 53% in 2005; and
- 67% for developing major flood, compared to 72% in 2001 and 57% in 2005.

Success requires more written agreements, with each participating department knowing its role, providing resources needed to play its role, and helping test the plan in simulations and rehearsals.

Stations and Apparatus

Some stations lack specific features, which are required by current standards but were not required when stations were constructed. Some stations are old enough that a variety of persistent or recurring problems are to be expected and replacement might be better and even cheaper. Some departments are using old fire apparatus.

- 48% of Kentucky fire departments do not have backup power for their fire stations.
- 48% of Kentucky fire departments do not have exhaust emission control for their fire stations.
- 30% of the fire stations in Kentucky are over 40 years old.
- 10% of Kentucky fire department engines and pumpers are at least 30 years old.

Cautions on interpretation

Trends. For some states and most needs assessment survey questions, even large changes from one survey to another will not be statistically significant. Be cautious in interpreting results as trends.

State-to-state comparisons. States where a large share of departments serve small communities will tend to have greater needs according to the measures used here than states where a small share of departments serve small communities. State-to-state comparisons must be viewed with caution, particularly if the states have very different mixes of urban and rural communities.

How rural is Kentucky? The survey for Kentucky was based on the following responses:

- 13 of the 26 departments protecting populations of 25,000 or more;
- 32 of the 76 departments protecting populations of 10,000 to 24,999; and
- 74 of the 589 departments protecting populations of less than 10,000.

Access the full state report, other state reports and the national reports at http://www.nfpa.org/needsassessment.

Source: Third Needs Assessment of the U.S. Fire Service, KY, NFPA, Fire Analysis and Research, Quincy, MA. October 2011

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