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A focused analysis on lean fire management systems

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Abstract
A primary role of the Incident Command System (ICS) is to learn from past incidents, particularly in the case of wildland fires. As such, a successful ICS application is critically dependent on its capability to function as a learning organization in order to continuously improve emergency response effectiveness. The objective of this study is to evaluate the potential to apply fundamental principles of the Toyota Production System (Lean manufacturing) to improve the learning effectiveness within the ICS. An in-depth review of literature and training documents regarding both systems reveals common goals and functional similarities, including the importance of continuous improvement. These similarities point to the validity of applying Lean principles to the ICS. Subsequently, a focus on systematic problem solving and the learning function of the ICS culminated in the discovery of gaps between the two systems. Finally, recommendations are made that the application of systematic problem solving including rigorous root cause analysis and effective standardization of successful problem solving countermeasures could be adapted from Lean principles in order to benefit the system.

Keywords*: Toyota Production Systems, Lean Manufacturing, Fire Management, Wildland Fire Management, Incident command System.*

1. Introduction

The objective of this study is to evaluate the potential to apply fundamental principles of Lean Manufacturing (LM) to facilitate continuous improvement of the Incident Command System (ICS). The ICS drives management of all major incidents including human and lightning caused wildfires in forests, grasslands, and preserved or monitored areas of the United States. The term “Lean” 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.

1.1. Wildland Fire in the United States

The inevitability of wildland fire occurrence has prompted dedicated annual seasons where precautions are taken and emphasized publically in hopes of reducing the frequency and severity of incidents. Since 2005, annual costs for wildland fire suppression have ranged from approximately one to two billion U.S. dollars for private, state, and federal land combined (National Interagency Fire Coordination Center, 2014). *Figure 1* illustrates the variation of wildland fire suppression costs form 2005 to 2013. According to the figure, suppression costs in 2013 reached $1.74B, a reduction from $1.9B in the previous year (National Interagency Fire Coordination Center, 2013). However, the National Oceanic and Atmospheric Administration (NOAA, 2012) classified 2012 as a warmer and drier year than average, which likely increased the risk of wildfires.

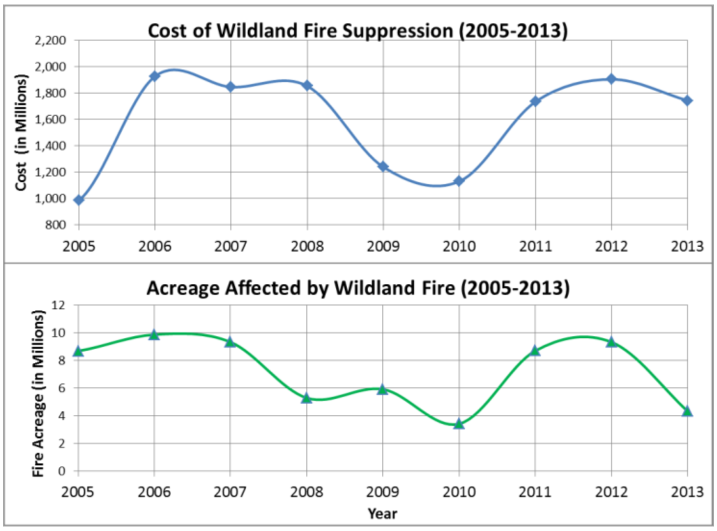

Figure 1. Wildland Fire Statistics (2005-2013) (National Interagency Fire Coordination Center, 2013).

ICS plays a key role in effectively managing hazardous incidents and preventing loss of valuable lives. To do this, ICS streamlines the overall decision making process to effectively cope with all aspects of urgency associated with wildland fire, ranging from strict monitoring of an incident to full extinguishment depending on geographic and fuel management considerations, proximity to wildland-urban interfaces (WUI), weather conditions, and available resources. .

2. Management Systems

Using available key references, the ICS is compared with a successful LM management system to identify similarities and differences. As main facilitators of the ICS use throughout the country, the Federal Emergency Management Agency (FEMA) and the National Incident Management System (NIMS) provide training documents, while the University of Kentucky's Lean Systems Program (UK-LSP) provides a variety of courses on LM principles and practices created through 20 years of close collaboration with Toyota. Over those 20 years, UK-LSP 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.

2.1. The Incident Command System

ICS is an expert system developed in response to lessons learned during past experiences. In the fall of 1970, southern California suffered significant fires that burned over 500,000 acres, more than 700 structures, and caused 16 fatalities (Countryman, 1974). In response, the FIRESCOPE program was developed as "the first practical application of systems design to a major, complex wildland fire management operational problem." 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 (Chase, 1980). As part of the FIRESCOPE program, the ICS evolved throughout the 1970s and was implemented as a stand-alone management response system in southern California in the 1980s (Chase, 1980). Over time, the ICS proved its effectiveness in meeting the demands of each fire based incident by uniquely scaling an organizational structure and facilitating coordination of resources (Buck *et al*, 2006). In the early 2000s, the ICS was extended nationwide through the National Response Framework (NRF) to create a uniform management system for all incidents (not just fire related) under a National Incident Management System (NIMS). Today, the ICS emphasizes the importance of systematic problem solving and a standardized planning process to meet its objectives. These activities are supported by a dynamic organizational structure based on clear roles and standardized terminology (Deal *et al*, 2010; Emergency Management Institute, 2014).

2.2. Lean Manufacturing

The Toyota Production System was developed in response to lessons learned during past experiences, and thus, shares similar background with the ICS. 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 travelled to Japan to assist post-war recovery efforts. Deming introduced Japanese officials to the concept of statistical quality control (Deming and Orsini, 2013) and the idea that focusing on "built-in" quality rather than inspection could increase the quality of products or services without increasing costs (Deming, 1986). Deming also introduced the Japanese to the Plan-Do-Check-Act (PDCA) learning cycle, as well as his "14 Principles of Management" (Deming, 1986), both of which serve as the foundation for managing the ability to achieve and sustain built-in quality. Eventually these ideas were embraced and successfully implemented into many Japanese companie, including Toyota, who continue to apply them, eventually developing the Toyota Production System (TPS or Lean Manufacturing).

As it stands today, TPS places a great deal of importance on "providing products and services with craftsmanship, pride, zeal, history, spirit, joy, and more" (Saito *et al*, 2012) as well, the company strives to promote lifelong learning in its employees to produce well-rounded professionals who possess not only well-developed specialized technical skills but also overall knowledge and keen interest in continuously improving their work (Saito and Finney, 2014). Fujio Cho, the most respected world leader in TPS states: *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* (Saito *et al*, 2012), *offering service-oriented concepts to create a highly effective and efficient modern system consisting of people, information, machine and material* (Cho 1995).

The UK-LSP teaches a standard definition of what Lean should mean to an organization. The definition of "True Lean" is meticulously crafted as illustrated in 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 (Lean Systems Program, 2013). Each point of this definition holds a certain principle of TPS. The first point focuses on the workers and places them first in the definition of "True Lean," signifying their importance in the system. The second point states that there exists a systematic method of problem solving. 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. 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 (Lean Systems Program, 2013, Saito and Finney, 2014).

3. Discussions

The dynamic nature of the ICS mission is met using a best practices approach, which relies heavily on its ability to learn from previous incidents indicating that learning occurs not only on an individual basis, but also at an organizational level (Fiol and Lyles, 1985). The application of Lean principles and practices have been shown to greatly increase individual learning, and by extension, organizational learning (Maginnis, 2013). Because of this, Toyota has been called "the gold standard" of learning organizations (Liker and Hoseus, 2008). The PDCA learning cycle encourages the continuous improvement typical of learning systems because of its reliance on timely operational information feedback (Argyris, 1982, Spears and Bowman, 1999, Hall, 2006). The need to develop an everincreasingly effective learning organization provides a common goal for both LM and ICS, and indicates that the ICS could benefit in its efforts for continuous improvement by adopting Lean principles. To support this claim, we need to look closely at the ICS: their key functions and components.

Figure 2 provides a diagram of organizational structures and direction of communication flow for LM and ICS, where two-way communication and workforce education play a key role in success.

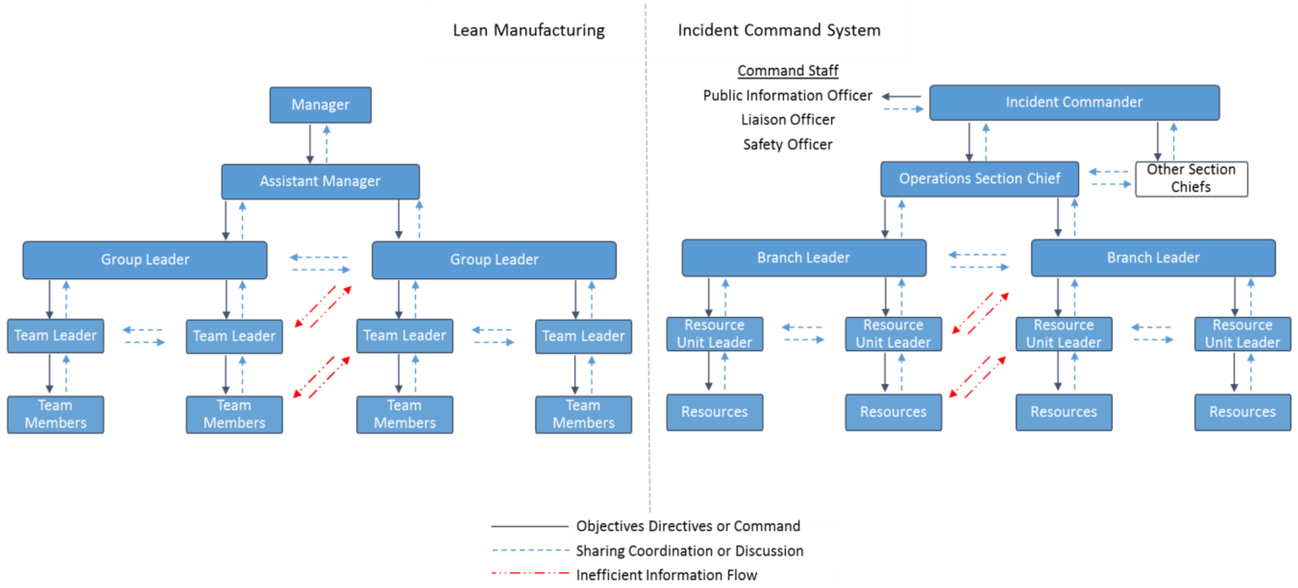

Figure 2. Comparison of structure, roles, and information flow for Lean and ICS.

Groupings within the ICS are comprised of 3 to 7 individuals per supervisor to improve management (Emergency Management Institute, 2014). Similarly, Lean systems employ the same type of control span for supervisors to have around 4 to 6 members reporting to them. Each system also has standards in place to inform workers of their role and corresponding responsibilities. In Lean systems, standardized work is developed and maintained to promote stability and recognition of abnormalities. Similarly, the ICS employs Standard Operating Procedures (SOPs) that promote the best known practices based on previous responses for the same purpose.

Figure 3 shows that the ICS problem solving method shares the same foundation of PDCA as LM problem solving, but that it differs from LM in one key aspect, the focus on problem recurrence.

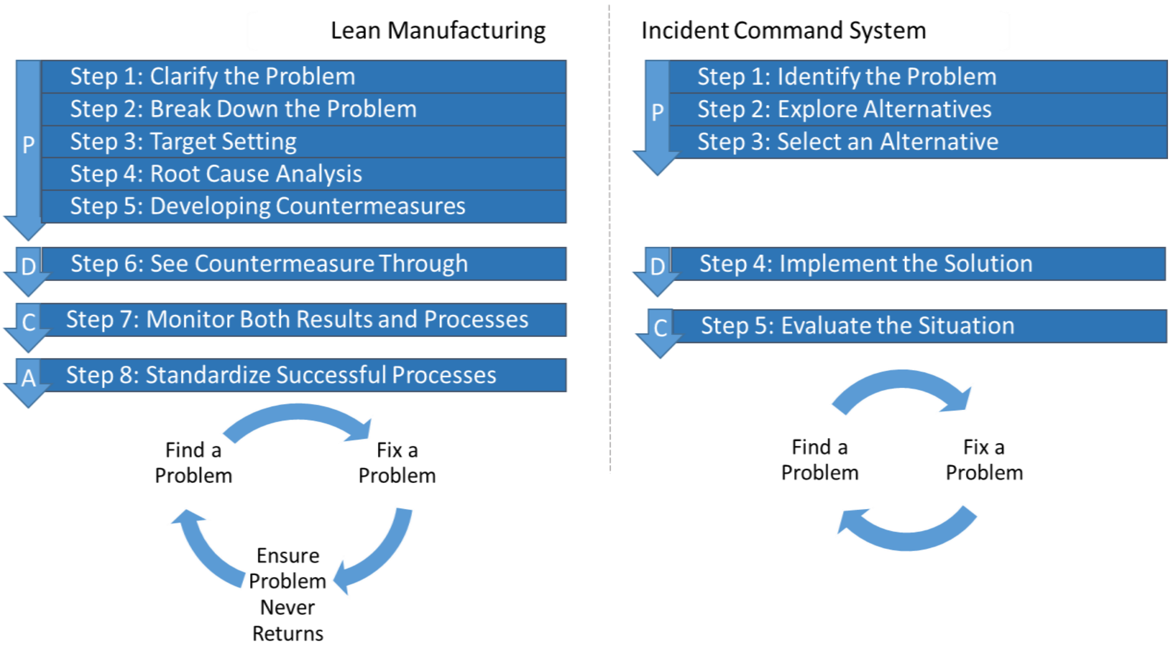

Figure 3. Comparison of Problem Solving Methods used in Lean and the ICS.

A high emphasis is placed on planning in both methods during the initial stage to better understand a problem and develop effective solutions. The ICS method has supportive materials to guide the user towards clarifying, breaking down, and setting goals for problems in the first step of its method (Emergency Management Institute, 2014). LM emphasizes root cause analysis and standardization of successful results following the PDCA to promote the cycle (finding/fixing a problem and tracing back to a root cause to prevent recurrence) (Lean Systems Program, 2013). Unsuccessful applications of LM typically result from an over-emphasis on immediate improvement which often ignores the importance of thorough problem solving and well maintained standardization (Angelis *et al*, 2011). The ICS training documents do not explicitly state standardization and incorporation as part of the current best method, but they are clearly required for continuous improvement, since resolving issues without finding the root cause will risk in recurrence of problems. The ICS process shown in *Figure 3* encourages finding and fixing problems, but will not prevent recurrence unless problems are traced to the root cause, and the results are incorporated into the standard procedures of the ICS.

Donahue and Tuohy (2006) recognized recurrence of problems in their analysis of learning capabilities within the ICS. 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 (Donahue and Tuohy, 2006). Moynihan (2009) further explored the concepts of organizational learning in the ICS 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 inter-crisis learning would effectively minimize the amount of intra-crisis learning required (Moynihan, 2008).

Figure 4 demonstrates the ICS cycle of continuously evaluating how effectively it responds through each iteration of addressing incidents (Fires 1,2,3,…,n). The ICS then uses this data from each incident to improve the efficiency of response and goes on to repeat the process.

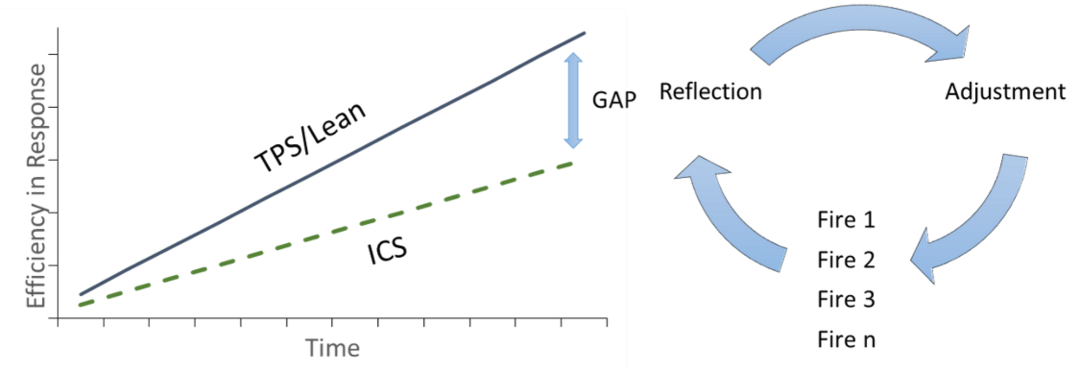

Figure 4. Anticipated Incremental Improvement of TPS/Lean organizations versus the ICS (based on Maginnis, 2013).

The figure also illustrates the anticipated gap that would occur between systems applying TPS/Lean methods and the ICS without root cause analysis and strict adherence to standardizing successful results (Maginnis, 2013).

4. Conclusions

The robust learning cycle present within the Lean method of PDCA facilitates continuous improvement when followed rigorously. This is due to a deeper level of learning achieved from investigations of root cause to eliminate problems (Tucker and Spears, 2002). 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 PDCA cycle, but if the system struggles with problem recurrence as suggested by the literature, application of root cause analysis may be able to significantly contribute to the effectiveness of future emergency responses. Furthermore, ICS 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.

Many factors are understood to impact the use and effectiveness of the ICS regardless of system design itself. Moynihan (2009) stated that barriers to intra-crisis learning 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 (2014) noted various factors regarding the application of ICS procedures within various emergency response areas. In order to improve the system overall, it is important to maintain continuous improvement efforts within areas that do use the ICS regularly, such as the firefighting community. These efforts would result in a model area of the system that demonstrates efficiency and effectiveness to lead by example and encourage further integration as a unified response community.

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