# *Understanding and Improving Engineering Change Proposal Development Efficiency in Raytheon's Logistics Management Information - U.S. PATRIOT Database*

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***Abstract*** *— This project aimed to raise efficiency for development and implantation per Class II ECP (Engineering Change Proposal). The task involved assessing the ECP development process and the intersectionality between inefficiency and knowledge gaps for new engineers. A Lean Six Sigma methodology was used and after a thorough analysis a resulting step by step guide was developed. Experimental data gathered from testing the tool showed a lower development time across a control sample of five small sized ECPs. The median reduction of time across the sample was 19%. Statistical testing was used to correlate the reduction of time with the use of the new tool. A Double-Sample-T-Test and a P-Value evaluation was used with resulting P-value of 0.0218. The P-value resulted under 0.05 significance level proving a correlation between use of the tool and lower development time. The problem was addressed successfully. Incorporation of tool and further development is recommended.*

***Key Terms*** *— Continuous Improvement, DMAIC methodology, Double Sample T Test, Lean Six Sigma, P-Value, Root Cause Analysis.*

## INTRODUCTION

The United States Department of Defense relies on engineers from private sector companies, such as Raytheon, to ensure that U.S. warfighter capabilities are the most advanced in the world. The lifecycle of the systems that are fielded in the U.S. Fleet go from initial design to deployment and sustainment. This project will tackle a problem in the sustainment phase of the United States Patriot System's life cycle.

Sustainment efforts are those that allow for the deployed systems to run continuously and with little to no unforeseen downtime. Raytheon Technologies works closely with the Integrated Fires Mission Command (IFMC) from the US Army to ensure that all procurement information in Line Replaceable Items (LRUs) for multiple systems, including all configurations of each, and the database of such are current and up to date. Raytheon's Logistic Management Information (LMI) section is tasked with analyzing and developing this information in the U.S. Patriot Database. These updates come via Engineering Change Proposals (ECPs)

Engineering Change Proposals are data packages that are created and approved by IFMC to support updates to the LMI database. This process is a complex one that requires multiple layers of knowledge, ranging from technical knowledge of the systems that the ECP affects, to that of understanding how to implement the developmental changes into the database. Engineers analyze these ECPs, translate them into actionable data that can be incorporated and baselined into the database, and develop/process these changes.

There are multiple levels of ECPs, lowest being a Class 2 (C2) change, highest being a Class1 (C1) DAMWO change. Currently, new engineers face a steep learning curve of for data development of these ECPs. Each ECP has global changes that need to happen, but they are tailored to the ECPs actionable change. Multiple shifts to the LEFT on delivery to IFMC have already happened and it is a current goal to improve.

### Problem Statement and Project Objective

The Logistics Management Information Section currently faces a backlog of ECPs due to a low number of engineers with the technical knowledge required to process these in the most time efficient manner, creating a shift to the left on the timeline for processing. There is a steep learning curve for ECP processing knowledge. This is due to the fact that each ECP can be different in nature depending on the change that the customer might need.

The objective of this project is raising efficiency for development and implementation per Class II ECP. It is important to address this issue to comply with contractual responsibilities with the customer.

## LITERATURE REVIEW

Improvement is a concept that stems from human affinity to perfection. The concept of continuous improvement (CI) has been widely recognized and studied in academic literature, although there is no exact definition agreed upon by the scholastic community. “Despite the lack of consensus on its exact definition, CI is a widely recognized concept that has received extensive attention from the academic literature” [1]. For this project, the definition will be coined as “slowly but surely reducing waste in operations and thereby increasing the share of value-creating activities” [1]. The need to reduce waste and maximize profits has made a CI culture possible. CI in its origins was exclusively applied and intended for manufacturing operations. Currently, CI is applied to a wide spectrum of development work.

There are tools that have a proven track record of efficiency in CI. One of these is Lean. Lean management stems from the Toyota Production System (TPS), developed in the 1950s by Taiichi Ohno [1]. Another widely used tool is Six Sigma. Six sigma was created by Motorola engineer Bill Smith in 1987 [2]. The CI tool that will be used is a combination of the most recognized tools, Lean and Six Sigma (LSS). For over four decades LSS has been integrated into the fabric of CI culture in manufacturing industries. General Electric refined LSS by adding a fifth step, titled ‘Define’ in the early 2000s [3]. This action by General Electric lead to the creation of the world renowned DMAIC methodology consisting of five steps; The five steps being Define, Measure, Analyze, Improve and Control. This methodology, which be followed to raise efficiency in waste reduction on the processes, is an industry staple.

The integration of both Lean and Six Sigma tools integrated into a single process can be appreciated when initiating each step. A problem is clearly defined at the start of the process. In the measure and improvement phases Six Sigma is more prominent as one would create a Value Stream Map (VSM) of the current state of the problem to be addressed [3]. Later, in the analysis process, a VSM of the future is created. Once Improvement and control phases are reached, the tools from Lean are used.

There are multiple tools that can be used and both Lean and Six sigma have tools in common that will be used in this project. Two tools that stand out are Brainstorming and Process mapping. Other tools that are used are the Root Cause Analysis (RCA). For the Improve phase the RCA proves to be a tool that can be efficient in reaching our goals. The outcome of an RCA “are the contributory factors proximally leading to the incident, the root causes about latent factors from the system perspective and the action plans to prevent recurrence of similar incidents in the future” [4]; These results are what are needed for the completion of the objectives.

Understanding the context regarding CI and LSS is necessary to understand the objective of this project. Nonetheless, further contextual information is needed. The goal of this project is to Improve ECPs for a defense contractor. As stated by the US Department of Defense, an Engineering Change Proposal (ECP) is the management tool used to propose a configuration change to a CI and its Government-baselined performance requirements and configuration documentation during acquisition. [5]. The ECP has been for decades the tool the Government has used to track any changes to their database in relation to the property it owns and the equipment it uses for defense purposes in the U.S. Fleet. CI and LSS as a methodology can be used to improve development cycles for ECP processing.

The theoretical model to be used on this project is a Lean Six Sigma approach described in Figure 1, and a Double-Sample-T-Test and P-value validation. Figure 2 shows the script for the statistical analysis, which will be performed in Python programming language. With the calculated T-Value one can obtain for the P-value, which tells the probability of obtaining the observed difference in means between samples. A significance level of 0.05 will be used. A null hypothesis needs to be established. The null hypothesis for this project is that there is no relation between lower mean times and cost when using the solution created for our problem statement. If the p-value is less than the significance level, then the null hypothesis is rejected [6] and the project has a successful outcome.

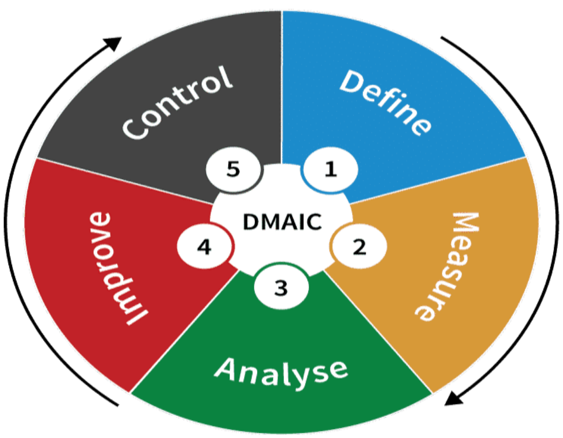


**Figure 1**
**Define, Measure, Analyze, Improve and Control Cycle**

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```python
import numpy as np
from scipy.stats import ttest_ind

# Original data in hours
original_data = np.array([100, 95, 97, 90, 80])

# Post-experiment data in hours
post_experiment_data = np.array([85, 72, 77.6, 70, 66.88])

# Calculate the t-test and p-value
t_statistic, p_value = ttest_ind(original_data, post_experiment_data)

print("t-statistic:", t_statistic)
print("p-value:", p_value)
```

**Figure 2**
**Double-Sample-T-Test and P-Value Python Script**

## METHODOLOGY

Using the theoretical model DMAIC, the methodology of the project is broken into subsections of tasking and objectives.

- Define - The goal of this stage of the process is to identify the problem and the main objective of the project. This has been stated on the Problem Statement section; Improvement of development time for C2 ECPs.
- Measure - Baseline data for development time in hours of small C2 ECPs was collected. Source was recently charged hours for entry level engineers.
- Analyze – A baseline for hours per ECP for development was established. A Five-Why-Root-Cause analysis was performed. After this analysis the root cause to be tackled was the time expended understanding the order of the steps for successfully provisioning data on the connectional provisioning database.
- Improve – A solution to the root cause was developed. A step-by-step list that would guide new engineers into successfully developing the main parts of an C2 ECP was created. This tool was tested by recreating five ECPs that had previously been developed. A new engineer with no knowledge was used as the control group. The charged hours using the tool was the data gathered.
- Control- During the control phase all analysis of data and interpretation was performed. Conclusions were drawn from the data and analysis.

## RESULTS AND DISCUSSION

Data gathered pre and post integration of tool to the LMI development process is graphically presented on Figures 3 and 4. Data collected with respect to time and cost is broken down per ECP on these respective figures. Cost was calculated based on hourly wage of entry level engineer ($36.53 p/h) multiplied by hours charged per ECP. Both figures reflect lower hours and costs for development of

ECPs post implementation of the new tool. By itself, it’s a first indication that the tool had a positive impact and raised efficiency of development. Even though the data does shows lower means for development time and cost, and it trends in the preferred direction as it was intended for the objective of the tool, is not enough alone to confirm a rejection of the null hypothesis.

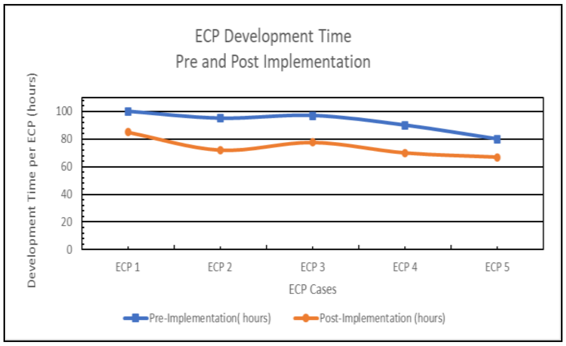


**Figure 3**
**ECP Development Time Pre and Post Implementation**

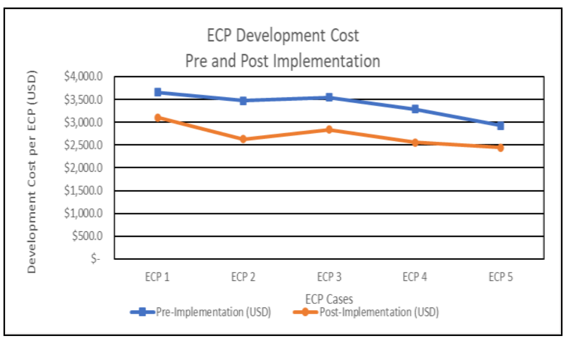


**Figure 4**
**ECP Development Cost Pre and Post Implementation**

Statistical analysis was performed to prove a correlation between the use of the tool and the lower trendline on Figures 3 and 4. To be able to perform this analysis, a deeper breakdown of the results was performed. Table 1 presents this breakdown for each ECP. The time and cost savings observed in the data is relegated on each row. The difference and percentage for each case is presented and the resulting mean difference of 18.10% was calculated. Table 1 shows there is an overall net positive median in terms of both hours and cost saved using the tool.

To be able to properly establish a correlation between the lower means and the usage of the tool a double-sample-t-test was performed using Python (See Figure 2 for script). The resulting value for the P-Value (probability coefficient) was 0.21 which is lower than the designated 0.05 significance level. In having a calculated P-Value lower than the significance level, the null hypothesis is rejected. This, in turn proves the correlation between using the tool and resulting lower means for processing time for ECP development.

**Table 1**
**Time and Cost Reduction per ECP**

| ECP Cases | Time Saved (Hours) | Cost saved (USD) | Savings % |
|---|---|---|---|
| ECP 1 | 15.00 | 548.08 | 15.00 |
| ECP 2 | 23.00 | 840.38 | 24.21 |
| ECP 3 | 19.40 | 708.85 | 20.00 |
| ECP 4 | 20.00 | 730.77 | 22.22 |
| ECP 5 | 13.12 | 479.38 | 16.40 |
| Average | 18.10 | 661.49 | 19.57 |

A graphical representation of the statistical analysis performed can be observed on Figure 5. Figure 5, a box plot of the time charged per ECP presents the post-experimental data having a smaller median and range of operation for development of ECPs than the original dataset. In addition to the P-value test results, having a post-implementation range that is completely below the pre-implementation further complements the rejection of the null hypothesis, confirming a correlation between lower means and tool usage. T

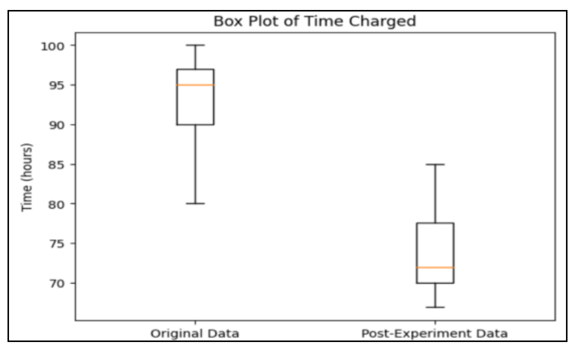


**Figure 5**
**Box Plot of Time Charged**

## CONCLUSION AND RECOMMENDATIONS

After reviewing, analyzing and performing statistical methods to the data, it can be concluded that there is a significant difference between pre and post implementation of the tool on the collected data sets. There is a correlation between utilizing the tool developed for this project and lower mean development time and cost for C2 ECP development.

The project utilized the DMAIC methodology. During these stages baseline data was established, a root cause analysis was performed, a new tool was developed, the tool was used, and experimental data was gathered. For the final stage of the methodology graphical and statistical analysis was used to support the hypothesis in place. This project tackled the problem statement by effectively raising efficiency on development time for C2 ECPs.

Multiple implications can come from this project for the workplace. The most important implication is that there will be a tool readably available for entry level and new LMI engineers. This tool will allow them to learn more in a faster paced manner how to develop C2 ECPs. In doing so, deadlines for the customer would be met, and lower costs would allow for more support for development endeavors.

This project is limited in the scale of operating the tool, both in sample size and capability for engineers. The control group for this project were engineers with no prior or small development knowledge. The result might vary if the control group has different levels of knowledge of ECP development. For further research, a bigger sample size and a bigger control group of engineers should be used. Further development of the tool can be used to include C1 ECPs and all the different levels of complexity on which C1 ECPs are available.

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