Applying Value-Focused Thinking to a Make Versus Buy Decision

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Abstract: The United States Army placed emphasis on decreasing the load an individual Soldier carries by reducing the weight of ammunition through the use of polymer-cased ammunition. This paradigm shift from brass to polymer raises concerns over the implementation aspect of this new procedure into the US Army's current ammunition production process. Our client, Project Manager Maneuver Ammunition Systems (PM-MAS) sponsored our team to analyze various candidate solutions using a methodology grounded in value-focused thinking, and recommend an implementation method to produce 7.62 mm polymer-cased ammunition at the Lake City Army Ammunition Plant (LCAAP) in Lake City, Missouri. This paper outlines the application of systems thinking concepts, various problem definition techniques and value modeling in order to effectively compare three given scenarios using a total value score versus cost analysis for each candidate solution. Our final recommendation is to implement the Buy scenario because of its total score of 63.5 and estimated cost of $14.62 million.

Keywords: Value-Focused Thinking, Polymer, Ammunition, Systems Thinking, Value Modeling

1. Introduction

The United States Army is constantly evolving through the use of new technology and resources to give its soldiers a strategic advantage over their adversaries while striving to maintain or reduce the individual load of a soldier. The weight of a soldier's individual load is a top concern of Army leadership and the Army's Project Manager for Maneuver and Ammunition Systems (PM-MAS) is currently exploring reducing the soldier's load through the use of polymers in ammunition (Lopez, 2016). Polymer-cased ammunition is significantly lighter than current brass ammunition. However, implementing the polymer-cased ammunition production process into the Army's current manufacturing framework at Lake City Army Ammunition Plant (LCAAP) in Lake City, Missouri creates its own set of challenges. PM-MAS asked our team to provide them with a decision on how to best implement polymer-cased ammunition into the current ammunition production process at LCAAP. Specifically, we were tasked to recommend an implementation method from amongst a Make scenario, a Buy scenario or a combination of the Make and Buy scenarios called the Buy-Hybrid scenario.

The Lake City Army Ammunition Plant located in Lake City, Missouri produced ammunition for the US Army in mass amounts since World War II. In 2001, LCAAP leased its ammunition production facilities and machinery to Alliant Techsystems (ATK) which currently runs the day-to-day operations of the plant. LCAAP currently produces over 1.5 billion rounds of ammunition every year for both military and commercial use. The current machinery at LCAAP is not capable of producing polymer-cased ammunition (Durkin, 2015). The implementation of polymer-cased ammunition at LCAAP would require significant modification to LCAAP's manufacturing process. These modifications may include altering or adjusting current equipment, purchasing and installing new equipment, building new facilities to house the new polymer-cased ammunition production process or a combination of two or more of the modifications mentioned.

PM-MAS focused our efforts on only analyzing the polymer-cased ammunition production for 7.62mm rounds. The 7.62mm round is a common caliber round the Army uses which is currently compatible with the M240 medium machine gun. The standard ammunition type these weapon systems use is the M80 ball 7.62mm round. However, there are additional variants of the 7.62mm rounds the polymer-cased ammunition must replace in addition to the standard M80 ball, such as the M62 tracer round and the M82 blank round.

2. Problem Statement

Assuming the US Army approves the use of the 7.62mm polymer-cased cartridge, recommend a method for PM-MAS to implement the Lightweight Small Caliber Ammunition (LSCA) production of 7.62mm M80A1 and M62A1 polymer-cased cartridges at LCAAP. Specifically, our team must recommend an implementation method from one of the three scenarios given by PM-MAS: Make, Buy, or Buy-Hybrid.

3. Background

Since the mid-1900s, the United States Military relied heavily on brass ammunition because of its highly effective way to construct durable and effective rounds in various sizes. However, there is one major drawback: weight. The standard infantry soldier operating a M240B machine gun will often carry 1,000 rounds of 7.62 brass ammunition. With each round weighing roughly 0.026 lbs., 1,000 rounds of ammunition adds an additional 26lbs to the load of a soldier (Lopez, 2016). Using polymer instead of brass in ammunition could reduce the weight of ammunition by up to 40% (Padgett, 2016).

An innovative way to minimize the weight carried by soldiers is the use of polymer in ammunition production, a technique the Marine Corps already plans to use for their future ammunition production. In 2004 the Marine Corps focused on developing a polymer alternative to the conventional brass cartridge-case ammunition (Hunt, n.d.). After years of similar research, the Army determined that polymer is a viable alternative to replace brass in the production of ammunition because of its ability to reduce the weight of 7.62mm rounds by 30-50 percent (Lopez, 2016).

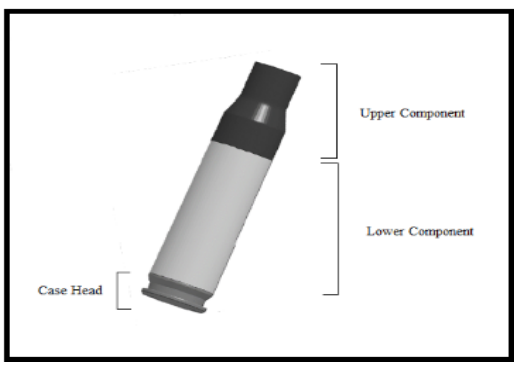

Figure 1. Three Piece Polymer-Case Design (Kim, 2013)

Our client, PM-MAS, is a subdivision of Program Executive Office-Ammunition (PEO-Ammo) and is leading the efforts to implement polymer-cased ammunition production for the US Army at the Lake City Army Ammunition Plant (LCAAP) in Lake City, MO. The challenge in choosing a method to implement polymer round production at LCAAP is determining which portion of the polymer case production process occurs on-site at LCAAP, and which portion occurs off-site at an external vendor's location.

A preferred vendor identified by PM-MAS currently makes the lighter polymer-cased cartridge for the commercial market using a three-part polymer case design (see Figure 1). This report uses the general structure of a three-part polymer case design as the default polymer case design when determining the implementation method to produce polymer 7.62 mm rounds at LCAAP. The bottom portion of the case is a metal head insert that contains the primer and holds the polymer to the bolt of the rifle. The case uses two separate polymer portions to increase the tightness of the seal in order to minimize blowback and misfires, as well as help maintain the cleanliness of the rifle. The middle polymer portion of the case requires injection-molding in order to connect this portion onto the metal head insert. The final neck portion of the case requires laser-welding to connect with the bottom half of the polymer case (Kim, 2013).

4. Methodology

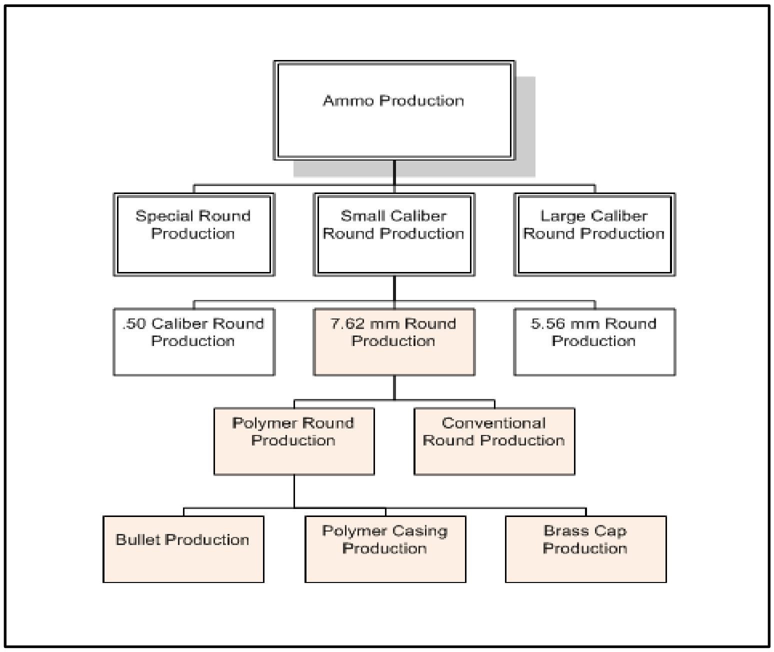

Figure 2. Spatial Arrangement

In order to effectively assess this problem, our team utilized the Systems Decision Process (SDP), a process created by faculty in the Department of Systems Engineering at the United States Military Academy. Dr. Gregory S. Parnell defines the SDP as a collaborative, iterative, and value-based decision process that can be applied in any system life cycle phase (Parnell, 2011). The recommendation in the form of a value-based decision is the desired end-state of this project.

Systems thinking played a crucial role by aiding our team's understanding of the problem and our ability to apply value-focused thinking. One of the biggest systems thinking concepts utilized was understanding the spatial arrangement of polymer-cased cartridge production. The spatial arrangement in Figure 2 displays how the 7.62 mm polymer-cased round production system, our system of focus, exists within and among other systems and the interaction, differences, and similarities between them. This diagram allows us to better scope the problem by demonstrating how this system interacts with its associated lateral systems, and how they all fit into the overarching meta-system of small caliber round production (Parnell, 2011).

Value Modeling is the cornerstone of our team's methodology. The Value Model contains two portions: the Qualitative Value Model and the Quantitative Value Model. The Qualitative Value Model, also known as the Value Hierarchy, reflects the client's and other key stakeholders' values regarding the decision at hand. This tool visually illustrated the values of the client and was essential in the evaluation of candidate solutions to the problem by providing our team with value measures (Parnell, 2011). Value measures (see Table 1) provided a way for our team to measure how well a function of the system is or is not performing. The Quantitative Value Model formed the basis of our mathematical model that allowed our team to determine how well the Make, Buy and Buy-Hybrid scenarios attain the values of our client, PM-MAS (Parnell, 2011). The Quantitative Value Model consisted of two major components: Value Functions and Swing Weights. Both of these components work together in the additive value model to give a total value score to a candidate solution. In this case, value modeling enabled our team to give total value scores to the Make, Buy and Buy-Hybrid scenarios.

Table 1. Value Measures

Value Measure	Unit	Definition
LCAAP Workspace	Square Feet	Amount of area at LCAAP used for polymer production
Brass Capacity	Rounds Per Year	Rate at which LCAAP produces brass 7.62 mm cartridges
Time to Full Rate Production	Months	Time required from decision to full-rate production. This would include the time it would take to install or convert equipment, building new structures, converting current work space and hiring/training people.
Capital Investment	Dollars	Amount of upfront costs associated with either the make, buy, or buy-hybrid scenario.
Polymer Capacity	Rounds Per Year	Rate at which LCAAP produces polymer 7.62 mm cartridges.
Workforce Impact	Number of Workers	Number of workers required to implement recommended solution.
Quality	Number of Machines	Number of inspection machines utilized in the recommended solution.

Our team created value functions for all seven value measures in order to measure returns to scale on each value measure. Returning the measures to scale for all value measures gives our team the ability to compare value measures on the same scale – value (Parnell, 2011). For each value function the x-axis is the scale of the value measure where the minimum threshold (lower boundary) and the ideal (upper boundary) were prescribed by the client. For each value function the y-axis is a standard unit of value measured from 0-100. The minimum threshold always receives a value score of 0 and the ideal always receives a value score of 100. Figure 3 depicts the value function for the value measure *LCAAP Workspace* with a unit of measure of square feet. If one of our candidate solutions contained raw data of 15,000 square feet for the value measure of *LCAAP Workspace*, then that value measure would receive a value score of 40. Each candidate solution had all of its raw data for each of the seven value measures converted to value using value functions.

LCAAP Workspace

x	Value
1000	100
1500	90
2000	70
2500	55
3000	45
3500	15
4500	0

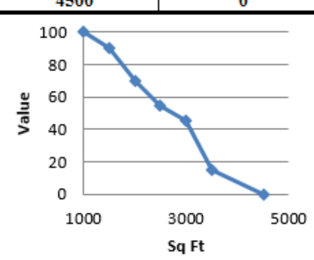

Figure 3. Value Function for LCAAP Workspace

In order to establish the priority of value measures, our team utilized the multiple-objective decision analysis concept called swing weights. The client weighted the relative importance of all value measures using values 5 – 100 with 100 being the most important and 5 being the least important. A value measure deemed less important than another value measure and whose changes across its range of possibilities had little impact on the decision was given a lower swing weight by the client.

Conversely, value measures deemed of higher importance and changes within its range of possibilities had a significant impact on the decision making process were given a higher swing weight value. Through a series of questions and a thorough discussion of the process, our team was able to elicit swing weights from the client for each of the seven value measures and normalized the swing weights to give each value measure a measure or global weight on a scale of 0.0 – 1.0. Table 2 depicts the swing and measure weights used in this project. Measure weights allowed our team to ultimately compare the relative importance of each value measure (Parnell, 2011).

Table 2. Swing and Measure Weights for Each Value Measure

Value Measure	Swing Weight	Measure Weight
LCAAP Workspace	50	.11
Brass Capacity	75	.16
Time to Full Rate Production	90	.19
Capital Investment	100	.22
Polymer Capacity	75	.16
Workforce Impact	5	.01
Quality	70	.15

Our client, PM-MAS, gave our team three scenarios or candidate solutions to compare using value-focused thinking. The Make scenario requires LCAAP to purchase and install all of the necessary machinery in order to produce an entire polymer-cased cartridge on-site. The Buy scenario requires LCAAP to purchase the completed polymer case from an external vendor, which would ship the polymer case to LCAAP for cartridge assembly and packaging. The final scenario of Buy-Hybrid combines the previous alternatives with LCAAP buying the unassembled sections of the polymer case from an external vendor, and completing only a portion of the case assembly process on-site. Upon completion of the case assembly, the remainder of the cartridge assembly and packaging processes would be completed at LCAAP.

5. Analysis & Results

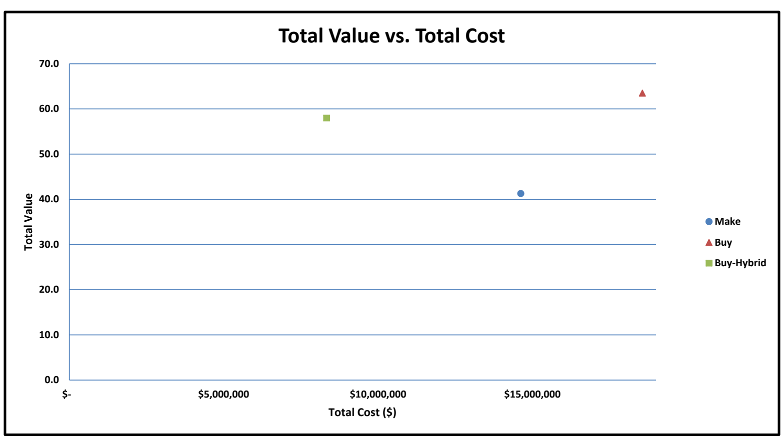

Figure 4. Total Value vs. Total Cost for Analyzing Polymer Production Implementation Methods at LCAAP

Each implementation scenario had its raw data for each of the seven value measures transformed into value using the value functions created as part of the Qualitative Value Model and then subsequently multiplied by their respective measure weight and aggregated for a total value score. Table 3 shows the total value scores for each of the implementation scenarios. The Buy scenario has the highest total value score of 63.5 and is our recommendation based strictly on value.

In order to conduct a value versus cost analysis for each method, our team collected data for various costs such as machine purchase costs, shipping costs, labor costs, raw material costs, installation and contracting costs. We collected this data through interviews with subject matter experts in their respective fields and created cost estimates for each implementation method. Figure 4 shows the relationship between value and cost of each alternative. The Buy and Buy-Hybrid scenario are feasible solutions and dominate the Make scenario because each has a higher value and lesser cost than the Make scenario. However, the Buy-Hybrid scenario, with the second highest value of 58.0, becomes our team's recommendation due to its cost savings of approximately $6.3 million while only decreasing in value by an extremely small amount. Choosing this method over the Buy scenario sacrifices only 5.5 points in value, but gives our client the opportunity to save approximately $1.8 Million for every value point reduced. If our client refuses to give up the 5.5 points in value, then the client can always choose the Buy scenario.

Table 3. Total Value Scores

Implementation Scenario	Total Value Score
Make	41.3
Buy	63.5
Buy-Hybrid	58.0

Sensitivity Analysis was also used to further validate our recommendation. Our team conducted sensitivity analysis on the swing weights elicited from the client to determine whether or not our recommendation would change based on changing the value of a swing weight for a single value measure while holding all other swing weights constant (Parnell, 2011). We determined the swing weights for the value measures Capital Investment, Quality and LCAAP Workspace were our most sensitive value measures.

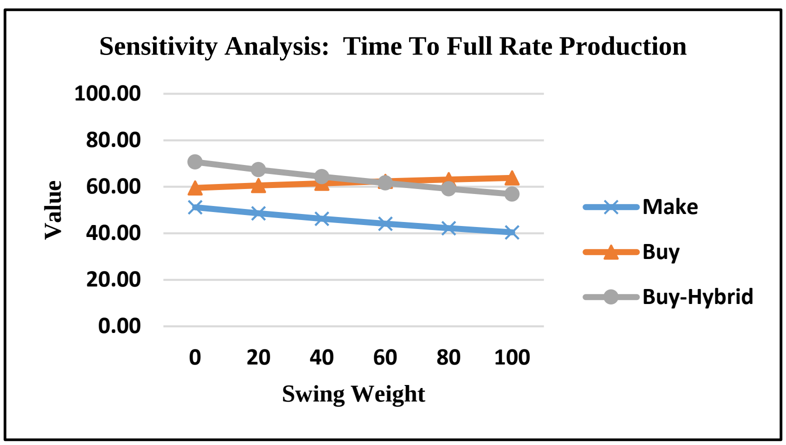

Figure 5. Sensitivity Analysis of Time to Full Rate Production

Figure 5 shows the sensitivity analysis for Time to Full Rate Production (TTFRP). The crossover point of the Buy-Hybrid and Buy scenarios at 58 illustrates the sensitivity of this value measure's swing weight. Changes to this swing weight value are not significant since the crossover did not fall within +/- 10 of the original swing weight of 90. The swing weights for Quality and LCAAP Workspace are also sensitive and follow the same logic as TTFRP. The crossover for Quality occurred at 50 and the crossover for LCAAP Workspace occurred at 70. However, since the crossover for both of these value measures did not occur within +/- 10 of their original swing weights, we do not consider this sensitivity significant enough to change our recommendation (Parnell, 2011).

6. Conclusion

Applying value-focused thinking to a make vs. buy decision allowed our team to provide PM-MAS with a value-based recommendation on how to effectively integrate 7.62 polymer-cased ammunition production into LCAAP. Through research, stakeholder analysis and applying a value-focused methodology, our team was able to create a value model that gives a final recommendation based on value versus cost. Our final recommendation to PM-MAS is to implement the Buy scenario for polymer round production at LCAAP because of its total score of 63.5 and estimated cost of $14.62 Million.

7. References

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