Using K-Means Clustering to Create Cost and Demand Functions that Decrease Excess Inventory and Better Manage Inventory in Defense

A STUDY OF EXCESS INVENTORY IN DEFENSE

History of Defense

- Prior to the Cold War total defense spend was 20% of Global GDP
- Excess was common as technology changes were minimal and parts could be reused, excess was not feared
- Being able to react to a situation was more important than budgeting – lives were at stake
- Profit was not the main focus, as defense is primarily government funded entities

Overview Of the Gap

- There is a lack of both literature and models on defense inventory problems
- Yet there is a distinct need for models due to the global excess
  - The GOA reported $9 Billion worth of excess in the US Armed Forces
  - The NAO reported £2.5 Billion worth of excess in the UK Armed Forces
- The solutions provided were only suited to disposing of inventory, not preventing the excess
- A model was needed that decreased the excess inventory, but maintained on hand part availability
  - Single Period
  - Little to no economies of scale

Closing the Gap

- Creating models that decrease excess inventory, while maintaining the on hand part availability through
  - Using K-means clustering to group parts
  - Creating cost and demand functions from cluster attributes
  - Aligning the procurement strategy to created functions

Case Study on DefenseCo

- Build large vessels for the Navy, only 3-6 vessels built per class
- Ordering and building begins before the design is completed

- 48,000 unique parts

270 suppliers

15 countries

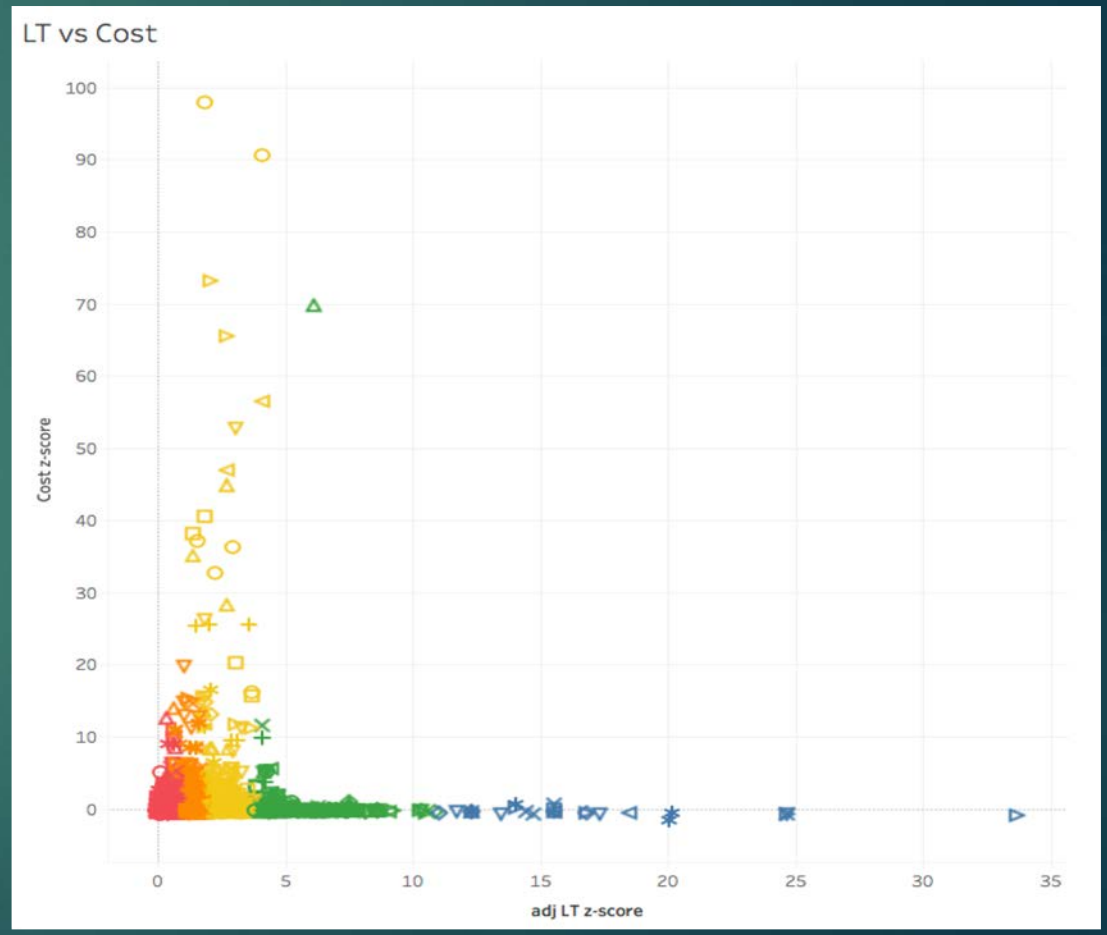
- 5 design and build phases that overlap
- Significant excess inventory and cost over runs

Methodology

1. Gathered part data and evaluated existing policies
2. Clustered data by Cost and Lead-Time using K-Means in Tableau
3. Create a cost and demand functions for each cluster
4. Tested functions on DefenseCo data, then on US Navy data

1-2 Data Gathering and Clustering

- Cleansed, standardized, and normalized data
- Clustered using K-Means based on Lead-Time and Cost
- Each of the 5 clusters had specific attributes that helped shape the cost function



Why create new models?

- Current literature did not have models appropriate for Defense
  - Single period models were based on the critical ratio
  - Defense cannot experience stock outs or back orders
  - Not driven by profit
  - Some parts have decay
  - Lead-times are in the years
- No model existed which took all of these attributes into account

3. Demand Functions

- Using historical data a probability of demand change and percent increase of demand table was allocated to each design phase.

Phase	Probability item not ordered yet will have an increase in demand	Estimated increase in demand
1	75%	25%
2	70%	20%
3	65%	15%
4	60%	12%
5	55%	10%

- Created a predictive Demand function based on Design Phases
- $\sum(1 + \pi_p)(D_i)$ where π is the phase, and p the percent increase
- Part is needed in phase 4, but has to be ordered in phase 3, the increase is 7.2% - $P(D_3|D_4) = 0.60 \times 0.12 = 7.2\%$

3. Cost Functions

- Each clusters' attributes formed the base for its cost function

Cluster	Color	Number of Parts	Total Cost	Average Cost	Average LT in Days	Max LT	Min LT	Average Delta in Days
1	Red	20,412	$5.9M	$290.5	34	96	0	4.4
2	Orange	13,772	$14.0M	$1,019.2	158	220	70	24.7
3	Yellow	5,875	$10.0M	$1,706.9	282	460	156	35.3
4	Green	703	$807.9K	$1,150.9	566	1,220	424	91.0
5	Blue	28	$28.3K	$1,048.6	1,875	3,787	1,242	1,029.3

3. Cost Functions

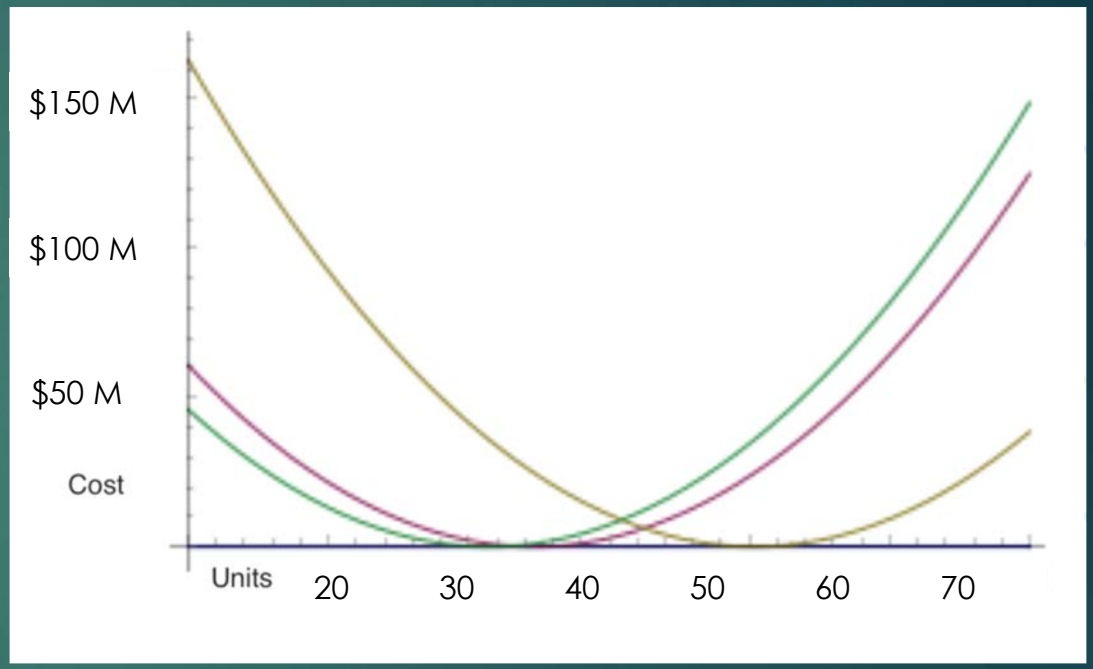
- Some clusters included a salvage value g, spares φ, decay $\varepsilon\left(\frac{1}{T_{EP}-T_U}\right)$, and a cost to rework items θ, each variable was dependent on its cluster attributes

- The overall Total cost function create can be seen below, though values were included or excluded depending on the part attributes of each cluster

- $$Total\ Cost = \begin{cases} c_i D_i + \delta(D_i - S_i)^2 - \left(1 + \pi_p\right) c_i D_i + \theta(X_i) + c_i \varphi;\ \pi_p > 1,\ D_i \geq S_i \\ c_i D_i + c_i h(T_{EP} - T_U)(S_i - D_i) - g(S_i - D_i) + \varepsilon\left(\frac{1}{T_{EP}-T_U}\right);\ T_{EP} > T_U,\ S_i > D_i \end{cases}$$

4. Cost Function Results

- The cost function was optimized in Excel using Solver using the predicted demand quantity, to find an optimized supply quantity that was the lowest cost
- The cost function reacts differently depending on the phase the item is required in



DEMAND RESULTS

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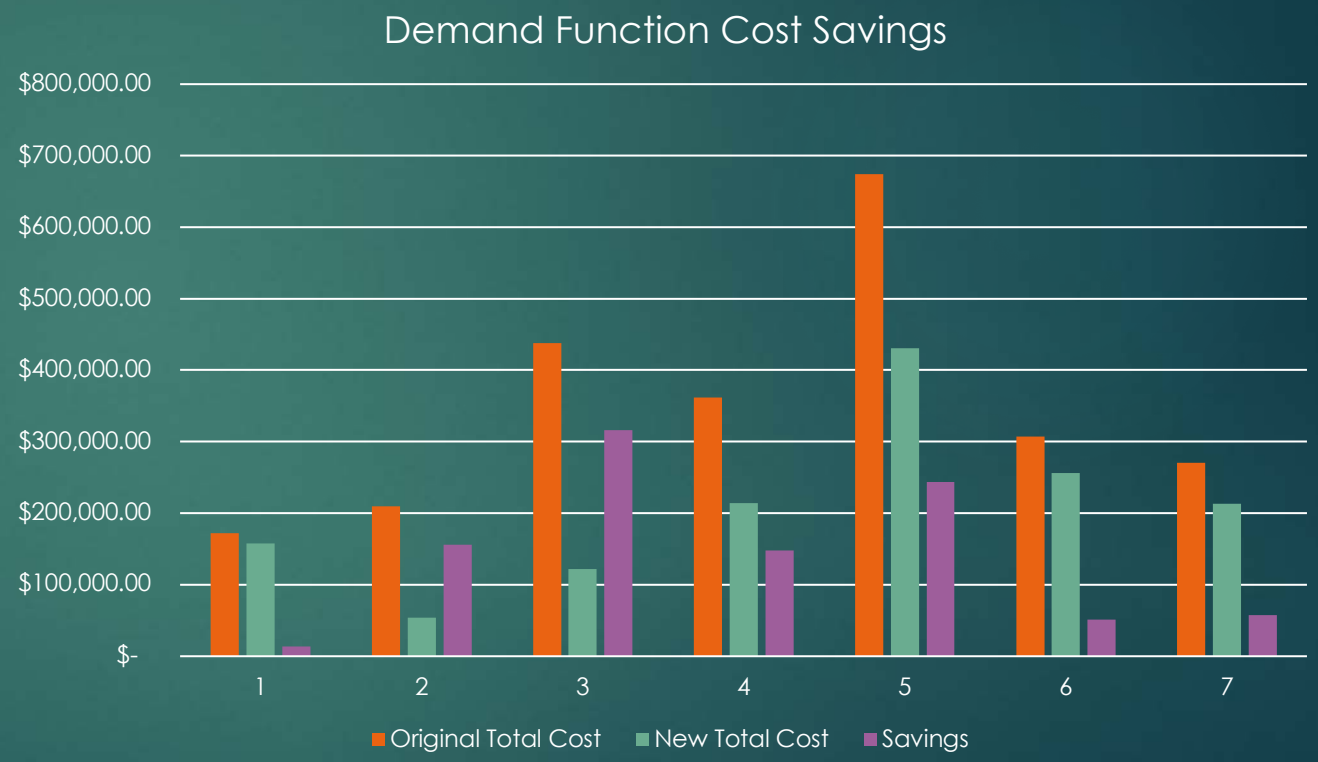
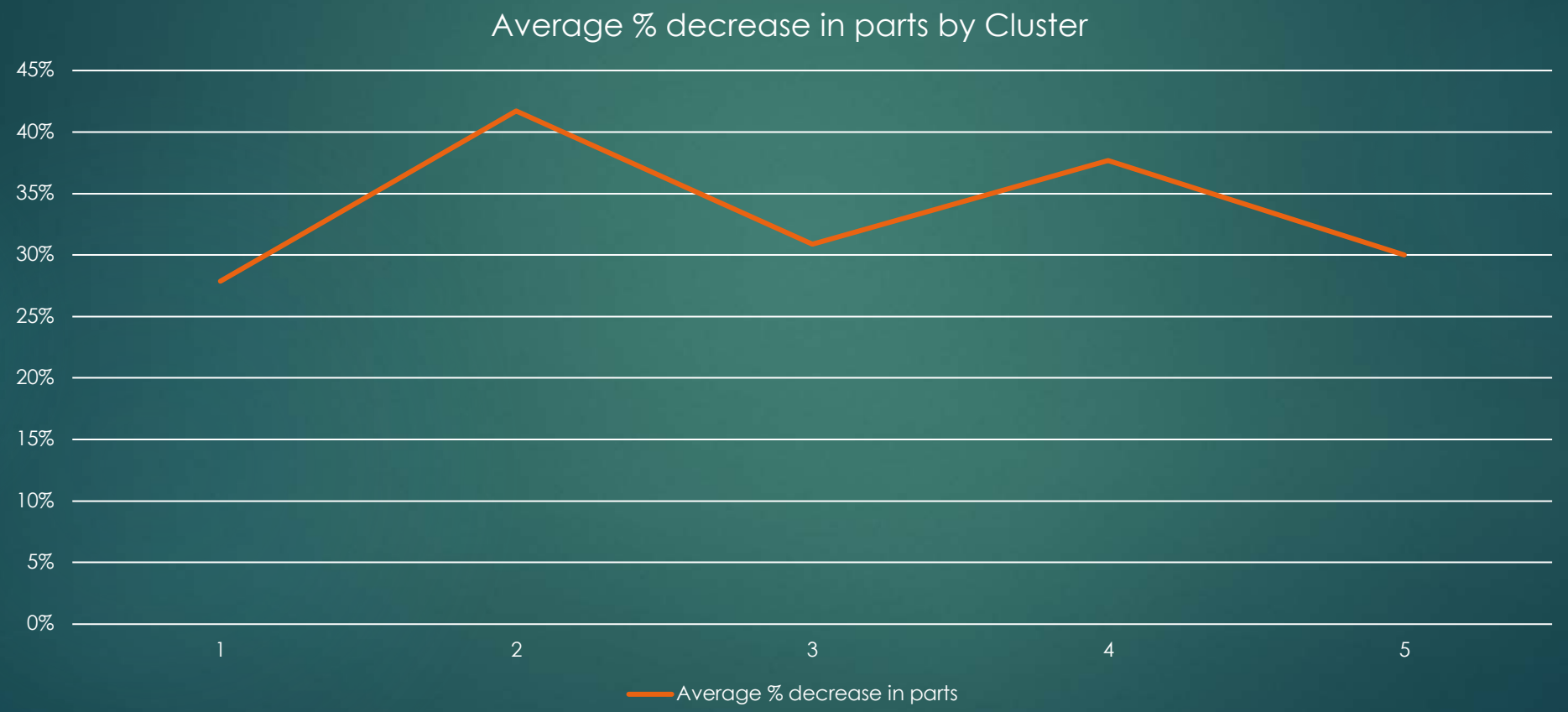


Results by Cluster



Overall results

For DefenseCo

- A 30% decrease in Excess Inventory using the new models
- A 51% decrease in Costs using the new models

For the US Navy

- A 31% decrease in Excess Inventory using the new models
- A 34% decrease in Costs using the new models

New Procurement Strategy

A new procurement strategy was created for DefenseCo based on the cost and demand functions:

- Order the optimized supply quantity when the lead time has been reached

Other Applications

These models are well suited for humanitarian aide programs as they are similar to Defense;

- Single period,
- No stockouts,
- Require instant access to parts on hand
- Government funded and not profit seeking

Thank You

- Questions & Comments