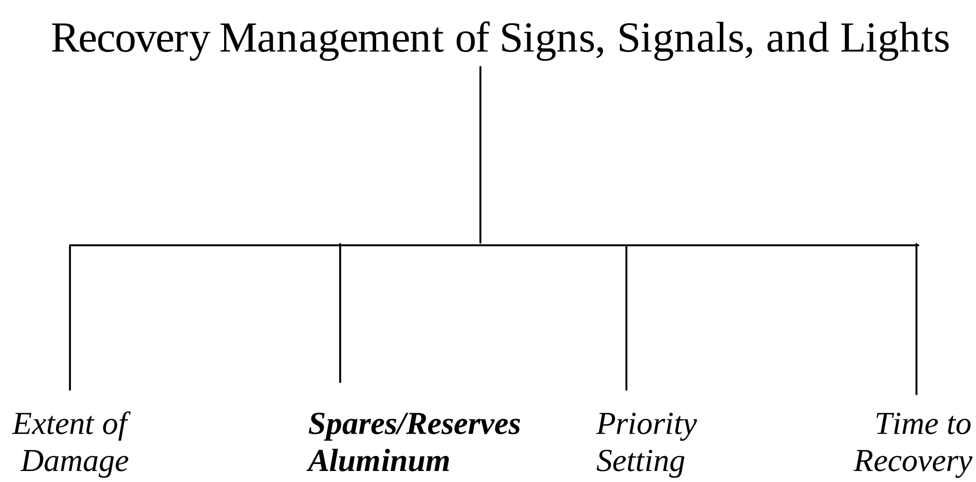
Chapter 3

Spares and Reserves of Aluminum for Street Signs



3.1 Introduction

The goal of this analysis is to develop a system of setting inventory levels of spares/reserves of aluminum and street signs that take into account potential widespread hurricane damage and to demonstrate the cost risk tradeoffs among alternative policies. This analysis is done through the inventory levels of aluminum that the Virginia Department of Transportation (VDOT) maintains for the production of road signs and through any contractual agreements that may be made to aid in emergency recovery processes. Road signs are an integral part in the economic well being of a community, and in the measurement of the speed in which a region can recover. VDOT currently uses a standard amount of aluminum for demands on a daily, weekly, and monthly basis. This demand is the result of events like worn out signs, vandalism, small storms, accidents involving the destruction of a sign, and the need for new signs where there was not one previously. The amount of aluminum used by VDOT will dramatically increase in the event of a hurricane. The current stock is not designed to handle that type of demand, and an increase in inventory sufficient enough to replace all damaged equipment is not cost effective.

This project follows specific steps of project completion, and consists of the following activities:

Background Research – Research on the Ford Motor Company and the Mobil Corporation were conducted through email interviews and telephone calls. Ford Motor Company has published material on inventory management, and information on the petroleum industry can be obtained from the American Petroleum Institute.

Comparison of Alternatives – The next step is to evaluate alternatives and rank them to determine the optimal strategy to embark on. This process is mostly formulated through the background research phase and only needs to be implemented.

Formulation of Model – Once an alternative has been chosen, the model must be formulated to specifically fit the context of the problem. In this project, the formulation of the model is the toughest task. The collection of data in a project of this scope is both time consuming and tedious. Information is assembled mostly through interviews and meetings with VDOT. A great deal of data comes from reports and journals requested by the group from VDOT

Validation of Model – After the model is formulated, a validation process must be performed to make sure that the completed model fits that context of the problem. This process includes draft copies of the preliminary report being sent to VDOT officials to get feedback and comments. This process was done in December, February, and March.

Verification of Model – If the model is significant and fits the related problem, then it must be verified to be mathematically correct and sound. This includes the process of checking all numbers that go into the graphs for errors and a general overview that checks the feasibility of the outcome.

3.2 Background

3.2.1 Introduction

Relevant literature has been reviewed to investigate background and developments in the field of extreme event consideration. The effect of extreme events on inventory has been a major concern to companies for decades. These extreme events can be forecasted, but the potency of the effects is random. A company must plan for the event with the available information in the most efficient and economical manner possible. Without a proper planning methodology, a company can experience extreme loss of revenue, customer satisfaction, or any other factor that directly contributes to the overall performance.

3.2.2 Ford Motor Company

Ford Motor Company currently has a large methodology to account for the effects of extreme events on its inventory of cars (Landvater, 1993). An extreme event to Ford would be a strike by the autoworkers, or the destruction of a main production plant due to a fire or other accident. This type of event can have devastating effects on the inventory of a large company like Ford. The demand for Ford automobiles will not drop a significant amount, and customers will still be looking for replacement parts and accessories. With a setback like a workers strike, the company will not want to jeopardize valuable customer relations due to lack of product. Ford must prepare for this event ahead of time. This type of incident may last a week, or it could last up to a couple of months. A workers strike can be predicted, but the full effects of the strike depend on too many factors to provide an accurate forecast.

3.2.3 Mobil Corporation

The Mobil Corporation is a large company in the petroleum industry. Mobil has concerns with its inventory of petroleum when a major event strikes. An oil strike or a major oil embargo can have significant effects on the inventory levels of petroleum. The

Mobil Corporation has vested interest in being able to continually supply its product to customers even when an event of this magnitude is effecting the industry. Mobil has a methodology for their inventory when a disaster like this is predicted to strike (Moore, 1977). This methodology includes the steps taken to prepare the company for the decrease in supply and increase in demand. This methodology can save the company millions of dollars in lost revenue and disordered customer relations. A methodology parallel to this could provide the Virginia Department of Transportation with the tools needed to provide a quick and efficient recovery process after a hurricane.

3.2.4 Metropolitan Dade County Florida

In the event of a major natural disaster, most state departments of transportation (DOT) will contract out some, if not all, of the work to be done in the long-term recovery of signs, signals, poles, and luminaries. A contract is rewarded to a company through the usual process of choosing the lowest bidder who can fulfill all the requirements specified in the contract.

In this particular contract, the company was to perform all work in the delivery of all supplies independently of the DOT. The Florida Department of Transportation (FDOT) included in the contract all the required materials for the contractor to obtain, and gave a time limit to fulfillment of the contract. The materials and all the subsequent hardware had to be delivered to the Dade County Public Works Department Signs and Signals Maintenance Yard Warehouse (FDOT, 1992). The time limit of this contract was 60 days for the delivery of a large amount of signs according to the following schedule (FDOT, 1992):

Table 3.1 – Sign Delivery Schedule for Contractor

Delivery Period	Stop Signs	Other Signs	Name Signs
1st Week	500	-	250
2nd Week	500	1/2	250
4th Week	2000	-	1000
6th Week	2000	1/2	1000
8th Week	-	-	1500

Problems that were run into during the process of fulfilling this contract were the difficulty in meeting the sign delivery schedule. The contractor could not get the supplies at the rate wanted by FDOT. Things brought up later that would have been beneficial include contracts with the suppliers. The contractor could have a contract with the supplier that essentially reserves a specified amount of aluminum and therefore eliminates the lack of supply. Along with this contract will be the provision that if the supply is not needed, the contractor will have to buy all the remaining stock for annual use. This technique will eliminate the problems with an increase in demand of aluminum. Another solution would be for the contractor to put in the order for the aluminum before the contract is signed. This can prevent problems and will be met with great caution due to the lack of security. The sign industry expects a 45-day period for the delivery of a usual order, and FDOT was asking for a great deal more in only 60 days.

Other problems with the contract were the slow delivery rate from FDOT on the different names that needed to be printed on the name signs. The contractor needed to fulfill the schedule on the contract for the name signs, but could not, without the proper information as to which names needed to be printed. The contractor also ran into problems with the late payment by FDOT. The payment for the contract was over four months late, forcing the contractor to take out loans to cover for expenditures.

The different problems associated with the Florida case can be avoided with the proper planning. A strong knowledge and quick delivery of which name signs need to be made, is essential in providing the contractor with the information that can help provide a timely recovery process.

3.3 Technical Approach and Analysis

Currently VDOT does not have a policy that covers extreme events, such as a hurricane, nor does it have a method to determine the amount of aluminum it should have in stock for the production of road signs. This model incorporates the possibility of contracting out the work to be done or just the production and delivery of all street signs by VDOT. VDOT cannot keep enough aluminum in stock to replace every sign after a hurricane, because the costs would outweigh the benefits. Storage is an issue because every sign is very large and requires storage space before it is used. There are costs associated with the storage as well as with the production and distribution of the road signs. All these factors are taken into account in the model to help VDOT find the optimal methodology that provides for the community, while keeping cost at a minimum.

Factors included in the analysis and preparation of framework:

- Level of inventory of aluminum
- Level of inventory of new signs

- VDOT Costs (To make the signs and keep in storage)
- Contractor Costs
- Time (To implement the use of the signs)
- External demands for aluminum (Outside of VDOT)

3.3.1 Operations Research and Inventory Theory

A mathematical model in the field of operations research fits this type of problem. In addition to research of the methodologies of other companies, an inventory model is developed to best optimize inventory during times of extreme demand. It is a technique that mathematically solves the general problem of allocating limited resources among competitive activities in a best possible way (Hillier, 1995). In a small firm a manager may keep track of his inventory and make these decisions. However, since this may not be feasible even in small firms, many companies have saved large sums of money by using "scientific inventory management." This includes the following steps:

- Formulate a mathematical model describing the behavior of the inventory system
- Derive an optimal inventory policy with respect to this model
- Frequently use a computer to maintain a record of the inventory levels and to signal when and how much to replenish.

Because inventory policies obviously affect profitability, the choice among policies depends upon their relative profitability or absence of cost for VDOT. Some of the costs that determine this profitability and apply to VDOT are (1) the costs of ordering the inventory (2) holding and storage costs (3) unsatisfied demand or shortage penalty costs. The cost of ordering the inventory combines the time and the actual dollar amount associated. This can also include any extra costs if a contract is made with the supplier that requires VDOT to purchase a set amount in a defined time period. The holding and storage costs include the amount spent keeping the signs in sign shops or in one of various warehouses. Unsatisfied demand includes the penalties associated with a lack in supply of signs when they are needed. The longer it takes for a community to be fully recovered, the more cost there is associated with dissatisfaction.

The following figure graphically represents the flow of aluminum and street signs for VDOT.

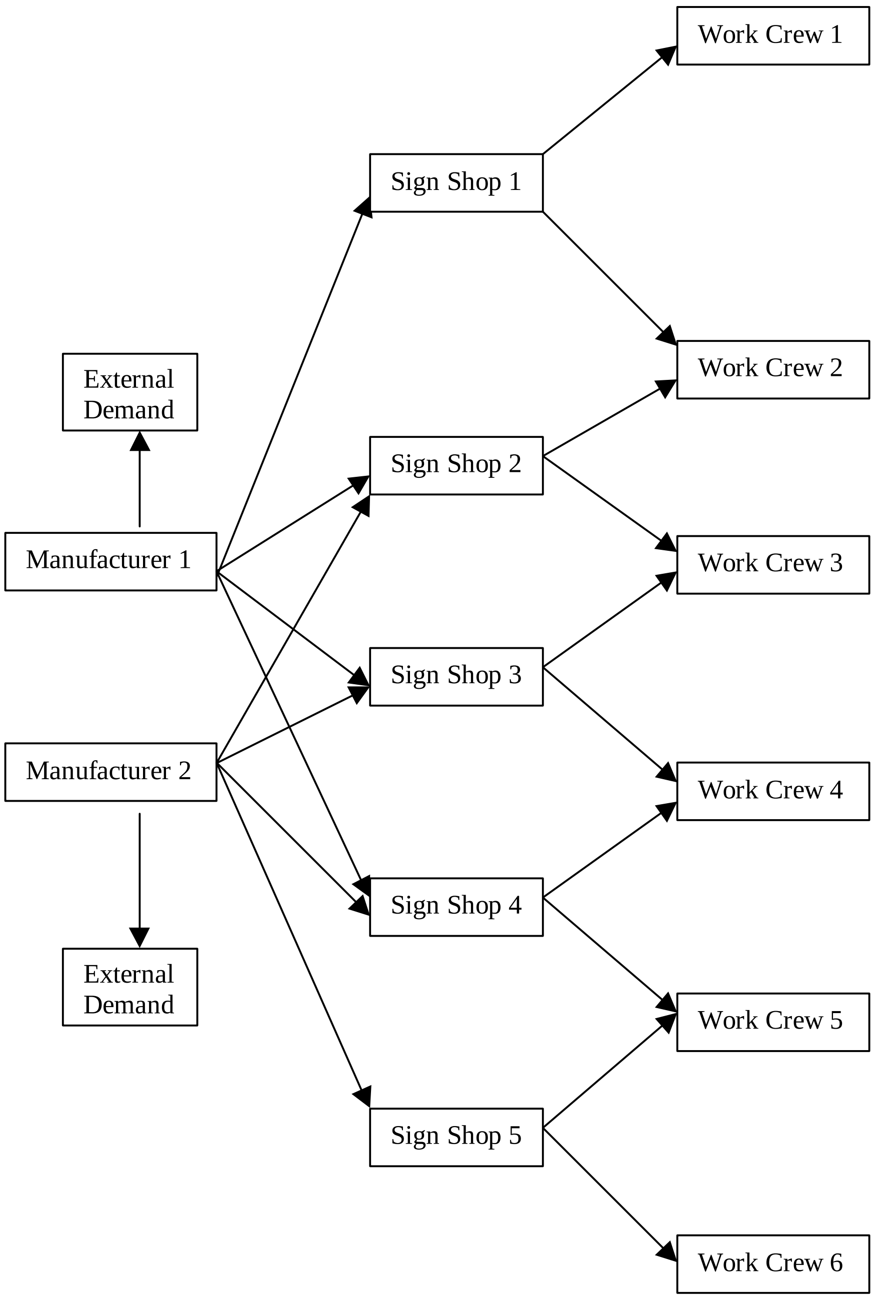


Figure 3.1: Flow of aluminum and street signs in VDOT

A manufacturer has to supply aluminum to both the sign shops of Virginia, as well as other customers, such as North Carolina. Each sign shop takes aluminum from multiple manufacturers and supplies multiple work crews depending on the location of the repair that needs to be done.

3.3.2 Data Elements

In preparation of the model, different elements had to be filled in order to make the recommendation realistic. These different elements include:

- Number of signs damaged in hurricane (ft^2 of aluminum)
- Cost to acquire materials for signs
- Production and Storage costs for the signs
- Costs to have contractor make the signs

The amount of inventory kept by VDOT depends on the cost of having the work contracted out when an emergency situation presents itself.

First, the amount of aluminum demanded must be quantified from the number of signs damaged in a hurricane. The amount of damage done by a hurricane will depend on the strength. Due to the scope of this project, every sign in use in the Suffolk district could not be counted explicitly, so an estimation is used. Two samples of roadway, five miles in length each, were taken from the Charlottesville area in order to estimate the average amount of signs in any five-mile stretch. Route 250 goes around Charlottesville and provides a good sample of what to expect on an average road stretch, and was therefore used in the sample. The result is Table 3.2:

Table 3.2 – Number of signs in sample stretch of roadway

	Overhead or bridge mount	Ground Mounted	Cantilever
6x10 (feet)	2	-	2
3x5	-	2	-
2x5	-	3	-
2x2	-	30	-
1x1.5	-	3	-
0.75x1.5	-	54	-
8x10	4	1	1
2x3	-	15	-
3x3	-	2	-
2.5x2.5	-	8	-
10x13	-	2	-
4x13	-	1	-
5x6	-	2	-
5x10	-	3	-
1x1	-	3	-
1x3	-	1	-
Average = 28.67ft^2			
Total	6	130	3

The different sizes of signs are standardized by a report given by the Purchasing, Inventory and Management System (PIMS) maintained by the Suffolk District Traffic Engineering section. The percentage of signs destroyed by different hurricanes depends on a damage analysis done in chapter 2. Chapter 2 associates the percentage of signs that will be damaged during different wind strengths and can be easily translated into how much aluminum is then demanded due to the loss of signs.

Table 3.3 – Amount of aluminum lost in a sample five mile stretch

Size (WxH)		**ft^2**	**Overhead**	**Ground**	**Cantilever**	**Total**
6.00	10.00	60.00	2.00		2.00	
3.00	5.00	15.00		2.00		
2.00	5.00	10.00		3.00		
2.00	2.00	4.00		30.00		
1.00	1.50	1.50		3.00		
0.75	1.50	1.13		54.00		
8.00	10.00	80.00	4.00	1.00	1.00	
3.00	3.00	9.00		15.00		
2.00	3.00	6.00		2.00		
2.50	2.50	6.25		8.00		
10.00	14.00	140.00		2.00		
4.00	13.00	52.00		1.00		
5.00	6.00	30.00		2.00		
5.00	10.00	50.00		3.00		
1.00	1.00	1.00		3.00		
1.00	3.00	3.00		1.00		
Amount of aluminum			440	1070.25	200	
Percent Lost in Category 1			0.00%	41.10%	0.00%	
Percent Lost in Category 2			0.00%	100.00%	0.00%	
Percent Lost in Category 3			47.50%	100.00%	68.00%	
Percent Lost in Category 4			100.00%	100.00%	100.00%	
Percent Lost in Category 5			100.00%	100.00%	100.00%	
Amount of aluminum lost in 1			0.00	439.87	0.00	**439.87**
Amount of aluminum lost in 2			0.00	1070.25	0.00	**1070.25**
Amount of aluminum lost in 3			209.00	1070.25	136.00	**1415.25**
Amount of aluminum lost in 4			440.00	1070.25	200.00	**1710.25**
Amount of aluminum lost in 5			440.00	1070.25	200.00	**1710.25**

The results of Table 3.3 are given in Figure 3.2.

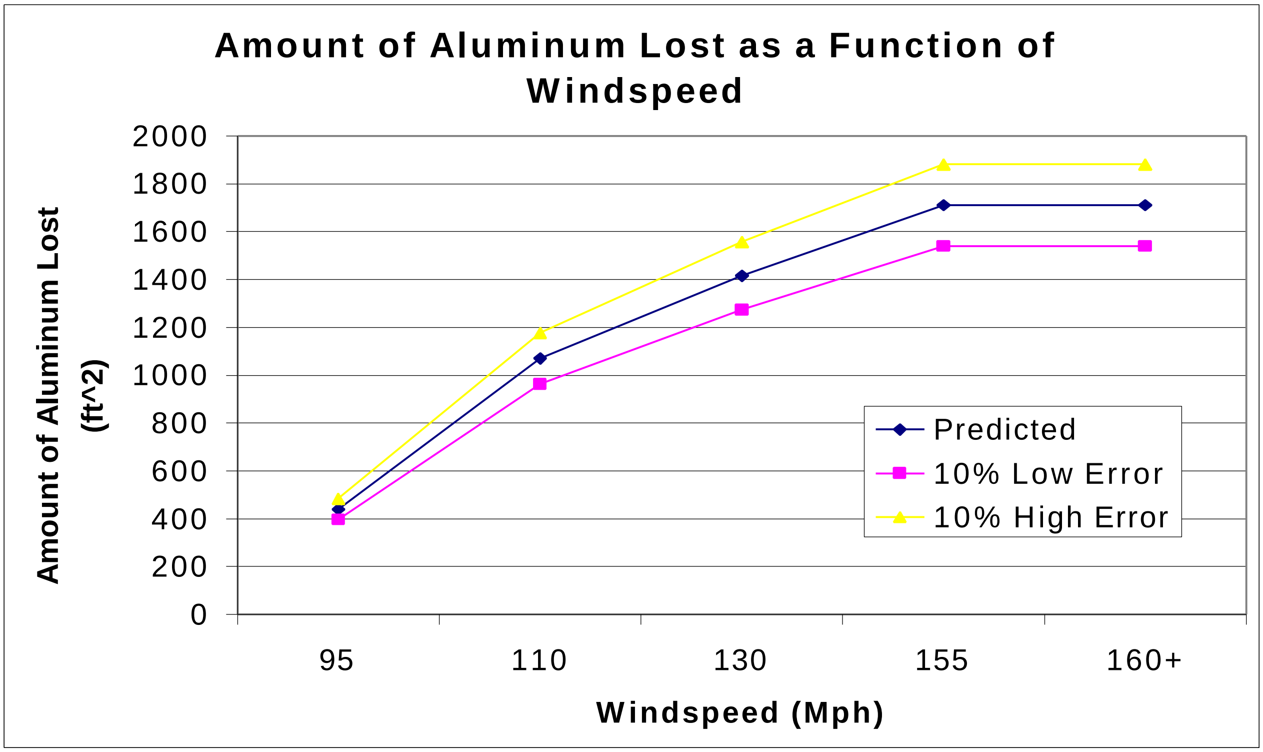


Figure 3.2: Estimation of aluminum lost due to a hurricane

Uncertainty is always present in a natural disaster, and this will be taken into account by providing a cushion in the analysis. The error associated with the loss of aluminum is the same as in Chapter 2, 10%. Each category of hurricane will have a unique demand associated with it. For VDOT, it may be realistic to have in stock enough inventory to cover for a category 1 and category 2 hurricane, but not for anything associated with a higher demand. The total amount of aluminum lost due to different wind speeds and associated hurricane category is the first element calculated for the overall framework.

The estimate of cost for VDOT to acquire the materials for sign production was given by the Suffolk District Sign Shop headed by Mr. Bert Shedum (Shedum 1998). He gave two examples of raw material, 42"x54"=$29 and 9"x48"=$6. Both of these are sheets of aluminum that are the standard 1/8 inch thickness. From these two figures, the cost of aluminum comes to approximately $2/ft^2. A complete table of cost and sizes is given in Table B1 in Appendix B. The production and storage cost for the aluminum must now be estimated to give an accurate number of the cost that will be presented to VDOT in the self-production of signs. A VDOT sign shop can produce approximately 7,000 signs per year. This production takes on an estimated cost of $17 per square foot. These averages are taken from the Suffolk District Sign Shop. The cost to store the signs is the relative cost of the building that the signs are stored in, and any associated expenditure that result from the structure. The cost of a warehouse breaks down to $5,000 per year. This is a fixed cost that does not depend on the amount of signs stored in the facility up to its maximum capacity of an estimated 100,000 ft^2 of signs material. This is represented in the Figure 3.3 (Table B2):

Figure 3.3: Cost of Storage of Signs for VDOT

From this, the total cost to VDOT to store any amount of sign can be calculated. The labor costs to VDOT amount to $650/day, the pay for fabricators in an eight-hour shift. Different methods of calculating the variables can easily be employed to further reduce any error associated with the inputs.

The cost to VDOT to purchase the signs from a contractor was estimated by contacted several current companies that commonly work with VDOT. Grimco Signs and Related Material in Missouri estimates for the price of signs, given in Table 3.4 (Grimco 1998).

Table 3.4 – Cost of signs from Contractor

	0-50	51-100 (10% off)	>100 (15% off)
6x10 (feet)	$1188.60	$1069.74	$1010.31
3x5	$297.15	$267.44	$252.58
2x5	$198.10	$178.29	$168.39
2x2	$79.24	$71.32	$67.36
1x1.5	$29.72	$26.75	$25.27
0.75x1.5	$22.29	$20.07	$18.95
8x10	$1584.80	$1426.32	$1347.08
2x3	$118.86	$106.98	$101.04
3x3	$178.29	$160.47	$151.55
2.5x2.5	$123.82	$111.44	$105.25
10x13	$2575.30	$2317.77	$2189.00
4x13	$1030.12	$927.11	$875.60
5x6	$594.30	$534.87	$505.16
5x10	$990.50	$891.45	$841.93
1x1	$19.81	$17.83	$16.84
1x3	$59.43	$53.49	$50.52

Table 3.3 gives a good estimate of the cost that VDOT has to pay to buy signs from a contractor and not to produce the structures themselves.

3.3.3 Results

It needs to be determined what type of policy for inventory and production VDOT should implement in order to have the most cost efficient recovery for the district. Using all the costs and variables, many inferences can be calculated that prove beneficial to VDOT. The cost of VDOT producing the signs for themselves is calculated first, then the cost to have all the signs contracted out, then a comparison and analysis.

If VDOT were going to produce all the signs for themselves in a post hurricane recovery effort, the costs would include labor, raw materials, production, and storage. In order to analyze this, each one of these variables must be put into a function of how much aluminum is lost due to wind strength. These variables can be summed up as follows:

$$\text{Total Cost of Material} = M(x) = 2x$$

$$\text{Total Cost of Production} = P(x) = 17x$$

$$\text{Total Cost of Labor} = L(x) = 0.85x$$

$$\text{Total Cost of Storage} = S(x) = \begin{cases} 5{,}000 & \text{if } x \le 100{,}000 \\ 10{,}000 & \text{if } x \le 200{,}000 \\ \dots & \end{cases}$$

These equations can then be used to find the total cost to VDOT due to any amount of aluminum lost from a hurricane. This cost represents the dollar amount to VDOT if all signs are made and produced by the state, represented in Figure 3.4.

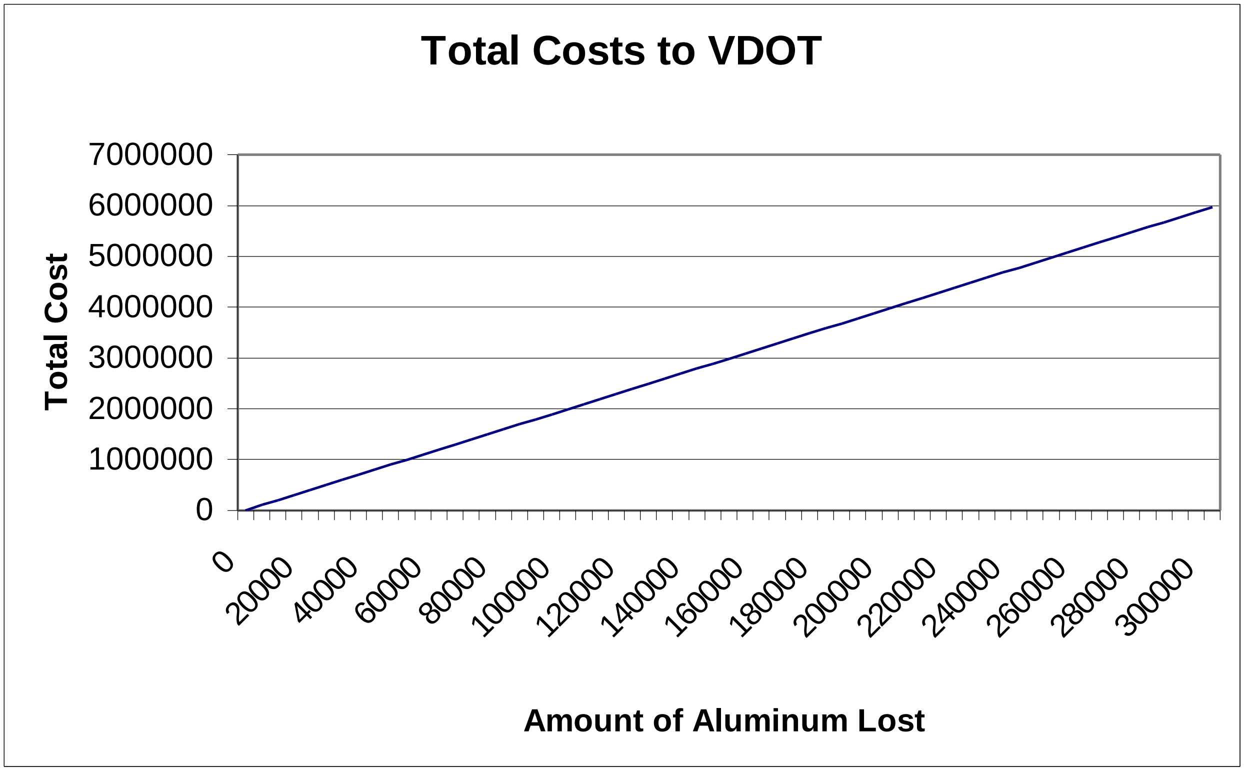


Figure 3.4 – Total Cost to VDOT as a function of aluminum lost

The jump in price due to an increase beyond the capacity of a warehouse did not affect the total cost enough to see on the graph (Table B3 in Appendix B).

The total cost to buy the signs from a contractor can be viewed as a function of the amount of aluminum lost due to a hurricane. From the prices in Table 3.3, a price per square foot can be calculated amounting to \$22/ft^2. Because VDOT would have to temporarily store the signs upon receipt, the cost of storage is factored into the overall cost of contracting out the sign work. This total is then plotted and given in Figure 3.5 (Table B3):

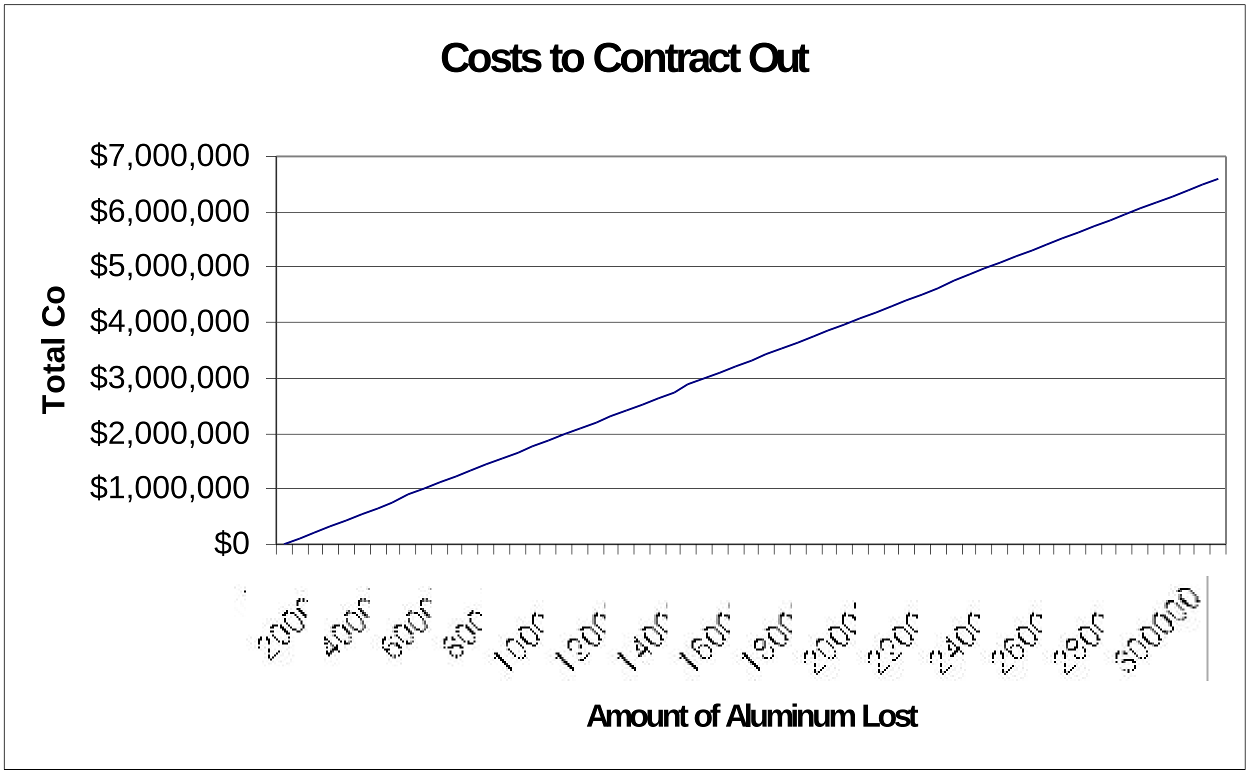


Figure 3.5 – Total cost to contract out the production of signs

The difference in the two policies can be seen in the graphs. The price to contract out all of the production of signs has a steeper slope then the price for VDOT to make all the signs for themselves. This steeper slope stems from the fact that the average cost per square foot for VDOT to produce the signs is $19.85, as compared to the $22 per square foot price of the contractor. In theory, this means that it is most beneficial for VDOT to produce all signs without the help of a contractor. Other factors must be examined to further this analysis, such as hidden costs (maintenance, raw-material price fluctuations) and money allocated by the state and federal governments to VDOT.

3.4 Recommendations and Conclusions

The final outcome provides VDOT with the information necessary in order to formulate a policy that is feasible and efficient. The information provided is based on the difference in the cost to produce all signs in the sign shops run by the state and the cost to contract out all work in the production of road signs. The difference in cost for VDOT to make the signs is less than for a contractor to make the all signs, but this does not tell how much preparation VDOT is prepared to have for a hurricane. VDOT must decide what level of hurricane is reasonable to be prepared for. For example, if VDOT wants to be able to handle up to a category II hurricane, it must be prepared to spend a specified amount of money that is determined by how much aluminum is lost due to that hurricane.

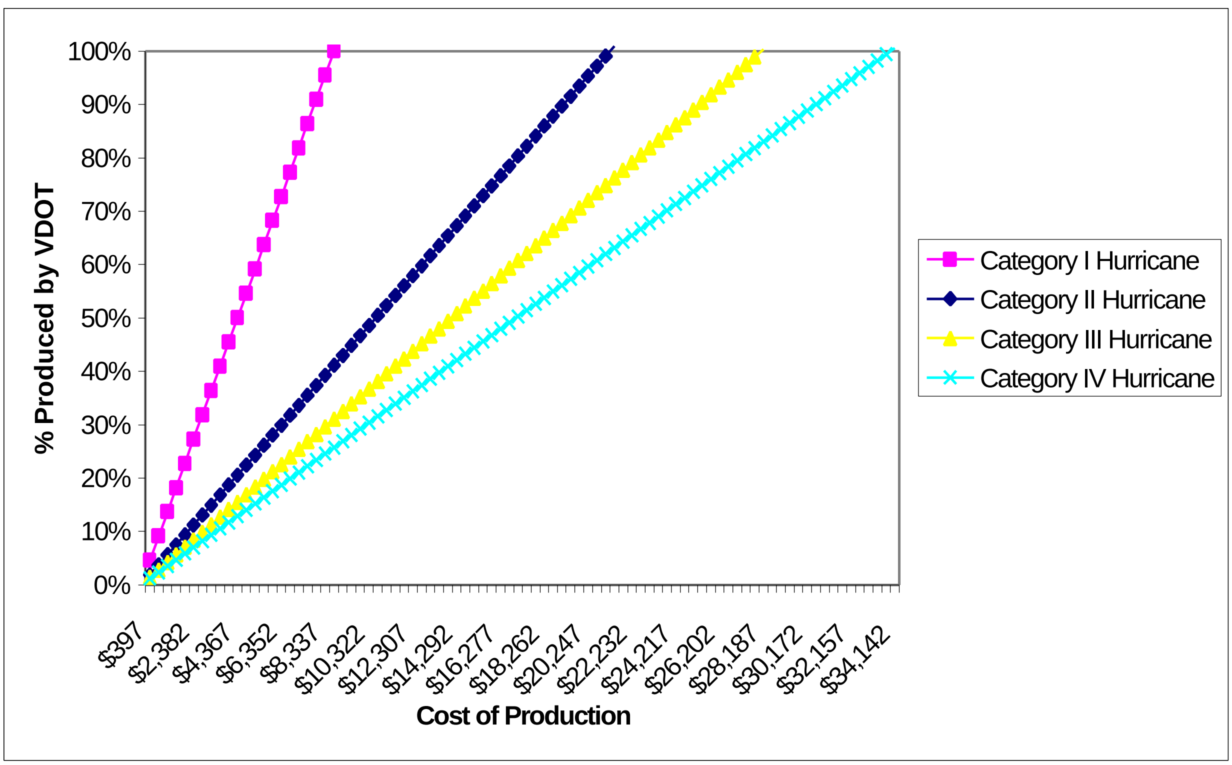


Figure 3.6 – Cost of Production vs. percent held by VDOT

The cost figures shown in this graph are only calculated for the two samples of roadway each five miles in length (Table B4). The ability to estimate the total amount of aluminum in the Suffolk District will be possible in the near future, therefore producing a realistic number for the entire district. Using this graph, VDOT can set a policy either based on the amount of money available, the amount of space available for storage, or the category hurricane that is deemed necessary to be prepared for in order to ensure an efficient recovery. An example of such a policy is shown in Figure 3.7.

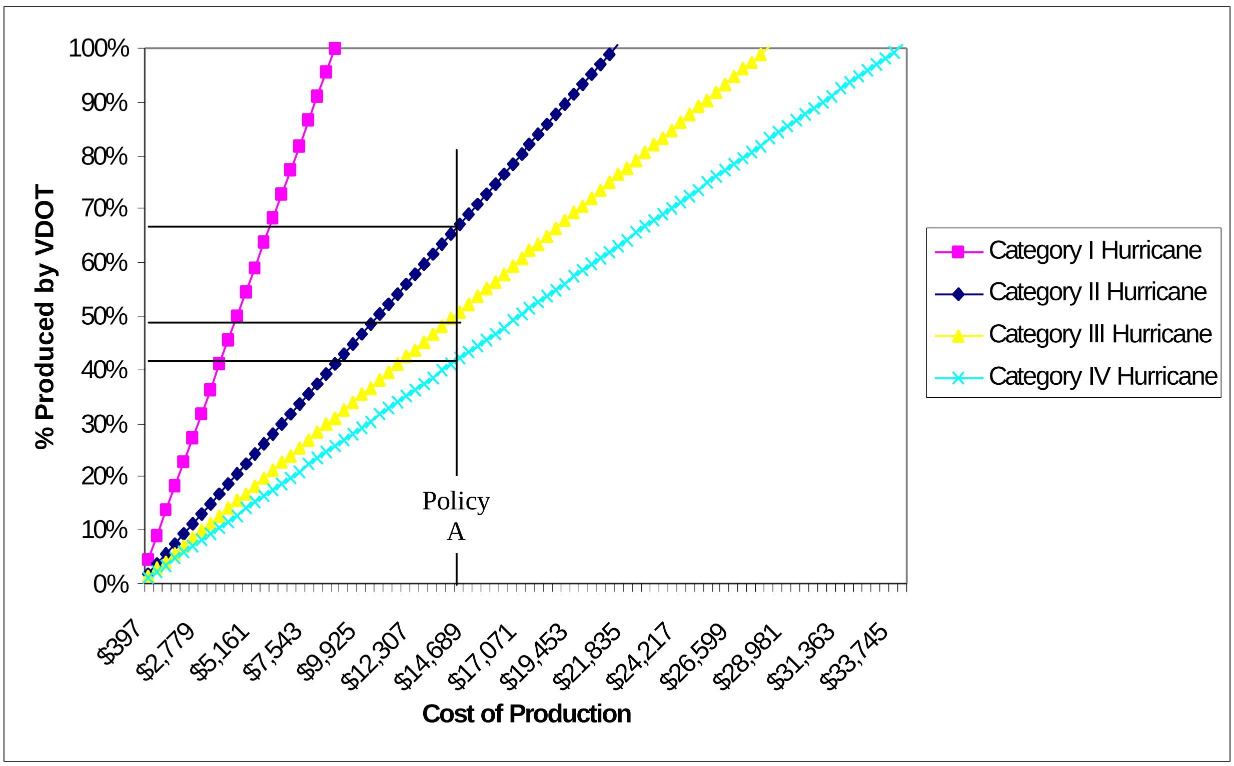


Figure 3.7 – Example policy with fixed expenditure by VDOT

Policy A is an example of a policy that VDOT could adopt in the recovery effort. This would be the case where there is a specified amount of money allocated to disaster relief. The graph therefore shows what percentage of damaged signs VDOT can handle. VDOT can also look at the problem from another perspective.

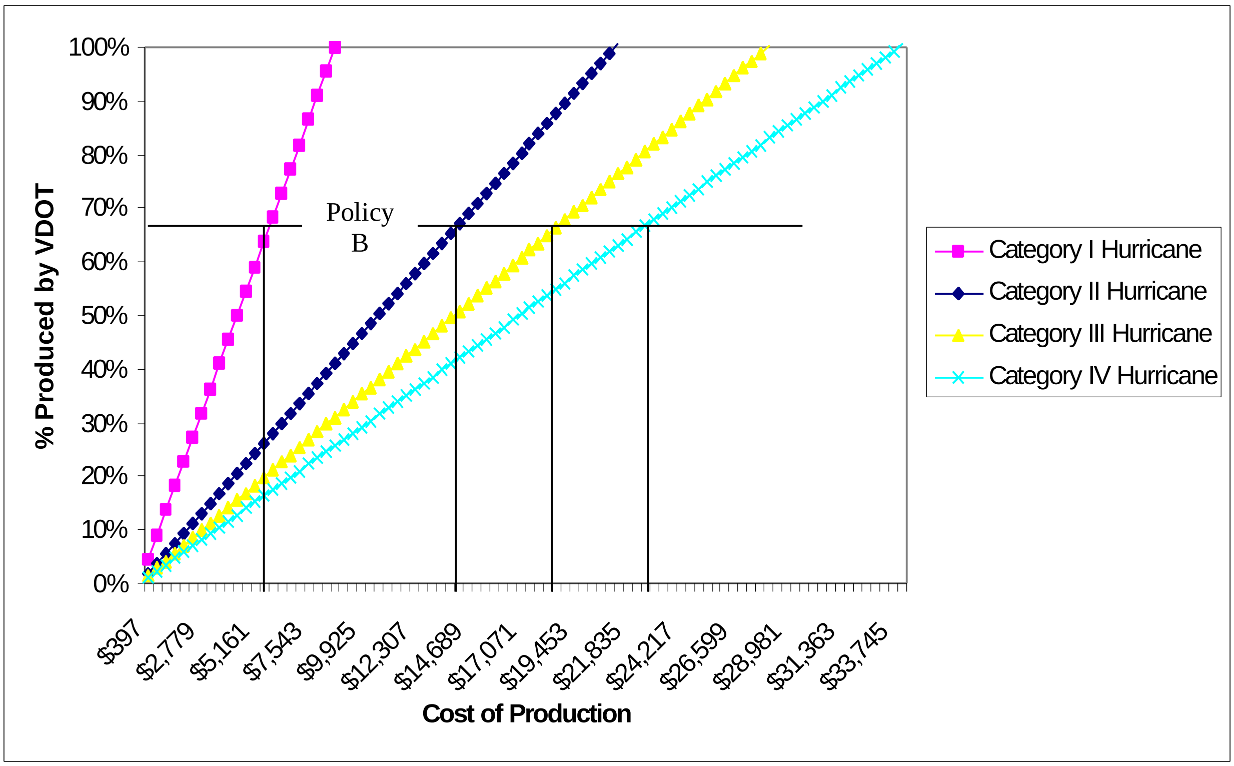


Figure 3.8 – Example policy with fixed percentage of recovery handled by VDOT

Figure 3.8 shows the scenario where VDOT feels it necessary to be able to recover for a set percentage of whatever type of hurricane strikes. This is the more probable of events, because it takes into account the amount of recovery that is provided for the community and the state. A myriad of policies is possible and one should be adopted by VDOT in order to ensure an efficient recovery.

In addition to helping VDOT set a policy for inventory management, this process can show that VDOT has a concrete policy in how much it spends during a recovery effort. This is vital in the effort to gain help from the Federal Government, especially FEMA. It shows that VDOT understands and can estimate the amount of money that is required for a full recovery effort by the state. Overall, the amount of damage done by a storm of high magnitude is highly unpredictable, and VDOT needs to adopt sound policies that structure the recovery effort in terms of the replacement of highway signs.