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Project Number: 41-CG02

CRITICAL REVIEW OF THE UNITED STATES COAST GUARD PORT STATE CONTROL PROGRAM

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
by

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Date: December 22, 2001

[Approved:]
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ACKNOWLEDGEMENTS

We would like to thank several people who were instrumental in the successful completion of this project. First, Dr. Frank Noonan played the all-important role of project advisor. We would also like to thank Lieutenant Commander Thomas Kuhaneck and Emanuel Terminella, both of the United States Coast Guard, for their efforts in securing the vessel data from the Marine Safety Information System.

ABSTRACT

This project was performed for the benefit of the United States Coast Guard Port State Control Program. Our aim was to increase the efficiency of the vessel targeting system. We planned on doing this by increasing specificity and reducing unnecessary boardings.

I. INTRODUCTION & OVERVIEW OF THE PORT STATE CONTROL PROGRAM

HISTORY AND PURPOSE

In response to an increase in sea-related fatalities, international and domestic maritime organizations began port state control programs. These programs incorporate flag state control, coastal policing, and vessel inspections.

In the United States, the Coast Guard carries the responsibility of maritime enforcement under its three primary marine goals:

> **Safety:** Eliminate deaths, injuries and property damage associated with maritime transportation, fishing, and recreational boating.
> **Protection of Natural Resources:** Eliminate environmental damage and natural resource degradation associated with maritime transportation, fishing and recreational boating.
> **Mobility:** Facilitate maritime commerce and eliminate interruptions and impediments to the economical movement of goods and people, while maximizing recreational access to and enjoyment of the water. (MSO Business Plan, 1999)

In the 1970's, the Coast Guard increased the inspection of foreign vessels to enforce new U.S. pollution and safety regulations. Guidelines for boardings began with the international guidelines for SOLAS and MARPOL.

SOLAS is the International Convention for the Safety Of Life At Sea. The first international maritime standard, SOLAS 29, required such basics as lifeboats and ship evacuation procedures. These mandates were a direct result of the sinking of the Titanic in 1912 (Marine Inspectors Course, 1997).

MARPOL is the International Convention for the Prevention of Pollution from Ships. MARPOL 73/78 is more than just a standard for operation of a vessel. This program provides standards regarding design, equipment, and survey requirements. The intent of MARPOL is to prevent pollution caused by accidents and routine operations (Marine Inspectors Course, 1997).

GLOBAL DIMENSIONS

Many countries have their own port state control programs, similar to that of the United States. These programs follow guidelines set by the International Maritime Organization for vessel safety and crew training. The regional entities meet and form Memorandums of Understanding (MOU) to share information about substandard vessels and port state control.

The Paris MOU is a consortium of nineteen maritime authorities, which are mostly from European countries (Paris MOU, 2001). The Tokyo MOU includes most Asian-Pacific countries. The U.S. Coast Guard is its Observing Authority (Tokyo MOU, 2001). There are several other memorandums, including the Acuerdo de Viña del Mar in Latin America, the Caribbean MOU, the Mediterranean MOU, the Indian Ocean MOU, the Abuja MOU in West and Central Africa, and the Black Sea MOU (Hare, 2001). These organizations coordinate the various administrative bodies that regulate marine travel in their respective regions.

All state agencies are a part of their respective MOUs. The MOU acts as a diplomat to coordinate the regulations these agencies enforce. Universal standards between countries prevent any one country from imposing stricter standards that may single out another country.

PORT STATE CONTROL OPERATIONS

The goal of the Port State Control Program is the safety of people, property, and the maritime environment. The Coast Guard aims to satisfy these goals without impeding mobility. However, they must do this with the resources they are allotted. One way the Coast Guard ensures safety is through foreign vessel inspections.

Each inspection involves the boarding of the vessel by a team of four Coast Guard officers (Next Generation Port State Control Targeting Matrix Business Case). For four hours they evaluate the ship based on factors such as crew performance and vessel integrity. Vessel inspections are deemed necessary through the use of a Targeting Matrix. This matrix analyzes each vessel by the following factors: owner/operator performance, overall flag state performance, overall class membership performance, vessel history, and ship type (Noonan, 2000).

A boarding can result in three possible outcomes. The first is that the vessel violates none of the regulations, and thus is compliant. If a vessel has any number of violations that are non-threatening towards the vessel, crew, or environment, then that vessel is deemed deficient. Each violation is called a deficiency. Vessels with deficiencies are still able to conduct operations normally. If a vessel is found to have severe violations then that vessel is detained. Detained vessels may not operate until their violations are corrected (Marine Safety Manual).

CURRENT PROBLEM SITUATION

The United States Coast Guard Port State Control Program was enacted in 1994. From 1995 to the present the federal government has either reduced or maintained the Coast Guard's overall budget. With fewer resources allotted, they needed a way to increase their efficiency. Since each inspection requires the resources of sixteen man-hours, efficiency may be directly improved by decreasing the number of boardings.

Seventy percent of the 12,000 annual inspections are compliant with the Port State Control Program's regulations. Only thirty percent of these boardings discover deficiencies and only two percent result in detentions (Next Generation Port State Control Targeting Matrix Business Case). The specificity of the PSC Program could be improved to reduce the number of compliant vessels inspected.

Specificity is the conditional probability that compliant vessels will not be inspected. The other performance measure is sensitivity. This is the conditional probability that the Targeting Matrix will indicate a boarding given that the vessel is non-compliant (Noonan, 2000). These two probabilities counter each other; increasing one typically decreasing the other.

PROJECT GOALS

The PSC program uses a profiling tool called the Targeting Matrix to target vessels most likely to contain deficiencies, and thus should be boarded. Currently, the matrix places the greatest weight on flag association. Statistically, however, vessel history is more directly related to the likelihood of deficiency, and thus may be a more accurate predictor. The current Targeting Matrix system uses detention history as the basis for evaluations (Noonan, 2000).

Our project group will assess the feasibility of improving the PSC Program's detection effectiveness by reviewing historical data of boardings from the previous three years. Through information technology we will employ various statistical techniques to analyze the vessel history. The boarding history data will be stored in a Microsoft Excel spreadsheet and manipulated with macros written in the Visual Basic programming language (Bronson, 1999).

Our next step will be to examine the data to find correlations between compliant vessels and their deficiency history. We will do this through the use of statistical analysis and moving averages. In a moving average, the recent past is analyzed to build a forecast of the future (Russell, 2000).

We will use our analysis to create a method that filters the results of the Targeting Matrix. A new system could be implemented to give the officers access to on-demand analysis of detailed vessel history. Information technology will be used to reduce the number of unnecessary boardings. This will increase targeting specificity and efficiency of Coast Guard resources without increasing the risk of substandard vessels going undetected (i.e. without decreasing sensitivity).

In Chapter Two we will discuss the details of the Port State Control Program's current operations, including the Targeting Matrix. Chapter Three will discuss the societal implications of the Program. The methods we used to analyze the data will be outlined in Chapter Four. We will then discuss the data and our analysis in Chapter Five. Finally, we present our conclusions and recommendations in Chapter Six.

II. PORT STATE CONTROL OPERATIONS

CURRENT TARGETING MATRIX

The Coast Guard implemented the Port State Control Program as a means to detect and eliminate the presence of substandard vessels in U.S. waters. The current PSC Program uses a system called the Targeting Matrix to identify incoming vessels that are most likely to contain deficiencies, and thus should be boarded. Refer to Figure 1 for the Boarding Priority Matrix. Before a vessel enters port, Coast Guard officials use the matrix worksheet shown below to assess the likelihood that the vessel is substandard. Boarding decisions are based on this likelihood.

1: **Boarding Priority Matrix**

OWNER	FLAG	CLASS	HISTORY	SHIP TYPE
5 Points Listed Owner or Operator	**7 Points** Listed Flag State	**Priority 1** ≥ 10 arrivals with detention ratio more than 4 times the average OR < 10 arrivals and involved with at least one detention in the previous 3 years.	**5 Points Each** Detention within the previous 12 months.	**1 Point** Oil or chemical Tanker
		5 Points ≥ 10 arrivals with a detention ratio between 3 & 4 times the average	**1 Point Each** Other operational control within the previous 12 months.	**1 Point** Gas Carrier
		3 Points ≥ 10 arrivals with a detention ratio between 2 & 3 time the average	**1 Point Each** Casualty within the previous 12 months.	**2 Points** Bulk Freighter over 10 years old.
		1 Point ≥ 10 arrivals with a detention ratio between the average and twice the average	**1 Point Each** Violation within the previous 12 months.	**1 Point** Passenger Ship
		0 Points ≥ 10 arrivals with a detention rate below the average OR < 10 arrivals with no detentions in the previous 3 years.	**1 Point Each** Not boarding within the previous 6 months.	**2 Points** Carrying low value commodities in bulk.

(Commandant US CG, 1999)

The matrix consists of five historical risk factors based on detention performance. These five risk factors are as follows: owner/operator performance, flag association performance, class association performance, vessel's historical performance, and vessel type (Noonan, 2000).

The owner/operator performance factor refers to any owner or operator whose vessels have been detained by the Coast Guard during the last twelve months. Owners and operators with poor detention histories are targeted because they are likely to repeat violations.

Specific countries are targeted when the intervention ratio for the vessels flying under that flag is greater than the average intervention ratio. The average intervention ratio is based on all ships that sail in U.S. waters and is calculated by dividing the number of detained vessels by the total number of vessels operating in that country. Also, at least one vessel from that country must have been detained during the last year (Port State Control Report, 1999).

Vessels can belong to various class societies. These memberships typically inspect the vessel and award certificates of compliance. Societies with high numbers of detentions are targeted because this shows that their inspections are not sufficient (Port State Control Report, 1999).

The Port Safety Vessel History is similar to the data that we use in our project. Vessels with detentions, casualties, pollution cases or marine violations receive points in this category. However, they do not take into account historical deficiencies (Port State Control Report, 1999).

The final risk factor, ship type, assigns points based on the relative risk of its cargo. Oil and chemical tankers as well as gas carriers have a high likelihood of creating an environmental disaster should they fail. This is exactly why these vessels are subject to more extensive inspections outside the scope of the targeting matrix. For example, liquefied natural gas vessels are inspected at sea seven miles from port every time they arrive. Bulk freighters over ten years old and vessels carrying low value commodities in bulk receive more points in the targeting matrix because they are more likely to be in a decrepit condition (Port State Control Report, 1999).

BOARDING PRIORITY

Each vessel's targeting matrix score is tallied and assigned a priority. Vessels receiving three or less points are deemed Priority IV, and rarely are boarded. Four to six points earn a Priority III label, meaning the vessel is usually not boarded. If a Priority III vessel is to be boarded, it will be examined when it arrives at the port without delay to its cargo loading. Vessels with between seven and sixteen points are normally boarded, and their cargo operations may be interrupted. Priority I vessels receive seventeen or more points and may not be allowed to even enter the port until the vessel is inspected (Port State Control Report, 1999).

In addition to the targeting matrix scoring, there are other qualitative factors that may push a vessel to a higher priority schedule. For example, vessels are required to undergo annual exams. Should a year have accumulated since an arriving vessel's last exam, it could be moved to Priority II or III, depending on its service type. Additionally, the Captain of the Port has the authority to decide if a vessel is potentially hazardous to the port or its environment, such as in the case of liquefied natural gas tankers. These vessels receive Priority I status (Port State Control Report, 1999).

Every foreign vessel that is scheduled to enter into a United States port must first go through this rigorous targeting matrix and priority assignment. Only then, if it meets all standards, is the vessel allowed to enter port. These methods help insure the safety of everyone in the port, as well as the crew of the ship and even the surrounding maritime environment. While these actions are necessary, they consume significant amounts of time and resources. And many times, the vessels that are boarded are completely compliant. By using information technology to value deficiency history in the boarding process, some of these compliant vessels may be avoided.

III. SOCIETAL IMPLICATIONS

When determining which vessels to board, officers must be aware of the consequences of their actions and extend proper courtesy when necessary. While the vessel is being inspected (for half a day), it cannot unload cargo nor continue to its next port. To the vessel's operator, that time is wasted. The Coast Guard must be aware of the domino effect of delayed shipments.

> If a chartered vessel is facing cancellation dates and is unable to complete loading or discharge by reason of a port state control detention, her owners would clearly suffer considerable financial losses. These losses may be mirrored down the charter party chain, and could be compounded by publicized allegations that the owner's hitherto good trading name has been tarnished. (Hare, 1997)

Many people are affected by the actions of the Port State Control Program. The crew of the vessel is directly impacted whenever the vessel is inspected. They are also at risk should they be allowed to continue operating an unsafe vessel. The owners of the vessels bear the financial impact of this program. Particularly in the case of passenger vessels, vessel integrity and safety have a direct impact on profits. Passengers will chose another cruise line if they feel one is unsafe. Freight vessels that have been detained in the past year cannot ship government-impelled cargo (Papavizas, 2001).

Every time the Coast Guard detains a foreign vessel, the potential for a diplomatic controversy arises. Public officials may have to arbitrate with foreign nations that feel they are being targeted unfairly. These are the direct participants in the system. There are many other interested parties, such as scientists who study marine pollution to know its causes.

FOREIGN POLITICS

By placing a heavy emphasis on targeted flag states, the Coast Guard has involved itself in international politics. A targeted flag currently gives a ship the seven points needed for a likely boarding under the current Targeting Matrix system. Ships with seven or more points are normally boarded, and ships with seventeen or more are always boarded. In 1999, the Coast Guard decreased the number of targeted flag states from twenty to fourteen. However, flag states with the highest detention rates are still targeted (Port State Control Report, 1999).

Figure 2: List of Targeted Flag States

Flag State	Detention Ratio	Flag State	Detention Ratio
Antigua & Barbuda	5.59%	Philippines*	5.14%
Belize	50.56%	Russia	5.83%
Cyprus	8.19%	Saint Vincent and the Grenadines	11.43%
Honduras	39.06%	Thailand*	7.23%
India*	8.94%	Turkey	11.41%
Malta	6.70%	Vanuatu	7.84%
Panama	6.92%	Venezuela	13.95%

*Countries that were not on the list in 1999.

Figure 3: Flag States Removed From the List

Flag State	Detentions in 1999	Detention Ratio (3 yr)
Cape Verde	1	60.00%
China	3	3.88%
Equatorial Guinea	0	28.57%
Mexico	0	11.11%
Netherlands Antilles	0	5.38%
Pakistan	0	36.36%
Romania	1	12.50%
Taiwan	0	4.07%
Ukraine	0	10.39%

(Port State Control Report, 1999)

In 1998, the Coast Guard inspected 7,880 of the 50,539 foreign vessel calls on port. Of these inspected vessels, 373 were detained (Port State Control Report, 1999). A significant portion of the detained foreign vessels was held for poor fire or abandon ship performance. The vessel operators were not able to operate fire extinguishers, lifeboats, or other necessary life-saving equipment. (American Maritime Congress, 2001) In 1999, twenty percent of detentions were the result of crews' poor performance during these drills. This number was down from twenty-five percent in the prior year (Port State Control Report, 1999).

In 1999, there were more calls on port by three percent fewer vessels (Port State Control Report, 1999). This indicates that each vessel was visiting ports at a higher frequency. The inspection rate decreased from twenty-five percent to twenty-two percent, and the detention rate decreased from nearly three percent to roughly two percent.

It is likely that the Port State Control Program is at least partially responsible for the increased training of crews. Vessel owners entrust valuable ships to their crews. Therefore they require trained crewmembers to avoid financial losses.

As businesses have become more globally aware, so too has the Port State Control program. Many maritime authorities, including the Coast Guard, publish their databases of vessel inspection history on the Internet to facilitate communication between regional inspection programs. This compilation may be used by researchers and statisticians to investigate the causes of maritime tragedies, in the hopes of preventing future catastrophes (IMO News, 2000).

IV. METHODOLOGY

RISK

There are two manners in which the performance of the Targeting Matrix can be measured. The diagnostic performance measures are calculated as conditional probabilities. A conditional probability is the probability of an outcome given a certain condition is true (Clemen, 2001). In this case, the two probabilities we deal with are sensitivity and specificity. Sensitivity is the probability the matrix will call for a boarding given the vessel is non-compliant. Specificity is the probability the matrix will not call for a boarding given the vessel is compliant (Noonan, 2000).

It was our goal to test the data we received from the U.S. Coast Guard in order to determine if past deficiency performance can be used as an indicator of the vessel's future performance. We aimed to increase specificity without decreasing sensitivity. We used a moving average as a tool to develop a historical summary for each vessel. The moving average method uses an average of the most recent *n* terms for a fixed sequence of periods. The terms we used in our study were historical deficiencies.

The formula for a moving average is:

$$MA_n = \left(\sum_{i=1}^{n} D_i\right) / n$$

where

n = number of periods in the moving average
D_i = demand in period i (Russell, 2000)

The moving average is frequently used in stock market analysis. By using a moving average, day-to-day fluctuations are reduced in importance and what remains is a stronger indication of the trend of prices over the period being analyzed. The moving average is based on the premise that the recent past is a good predictor of the trend. The length of the recent, past history affects the prediction of the moving average. The more historical terms that are used, the most stable the forecast. However, too many terms can make the forecast unresponsive to changes.

DATA ANALYSIS METHODS

In order to analyze the historical boardings we first had to manipulate the data into a form that would be easy for us to work with. When we received the data, each boarding was listed individually. Parameters of the original data set included Official Number, Vessel Key, Vessel Name, PS Case Number, Activity Date, Count of Deficiencies, Count of Controls, Flag, Service, and Cargo Type. The boardings that contained detentions were also listed in a separate file. We created a series of macros to make the job of formatting the data easier. Macros are small programs written in the Visual Basic programming language that automate repetitive functions in Excel.

The first macro, 'RemoveLess,' removed the entries of vessels with less than three boardings. In our analysis, the most recent boarding was used as the current boarding for comparison against the moving average. A minimum of two additional boardings was required in order to calculate a moving average.

The second macro, 'RemoveMore,' removed excessive boardings of vessels with more than eleven boardings. The oldest boardings were removed, leaving, at most, the eleven most current records. This was done to create a definite end point for the data set, where any record would have no more than eleven boardings in its history. Time series analysis is based on the assumption that the future is a continuation of the recent past. We limited the number of boardings we were dealing with in order to have a finite number of boardings, as well as keep them as recent as possible.

The third macro, ‘Merge,’ organized the boardings of each vessel into the format we needed to conduct the moving average. The data was listed by boarding when we received it, with over 37,000 boardings listed as separate occurrences. We needed the data to be organized by vessel, with each vessel having one record listing all boardings.

Our fourth macro we created was entitled ‘Detained.’ When we received the data from the Coast Guard, the detentions were listed in a separate file. Since we wanted to also take detentions into consideration, we had to move them from one worksheet into the worksheet we were working with. We then used our ‘Detained’ macro, which compared the VIN number from the detained vessel to the VIN numbers of all the vessels in the boardings worksheet. If it found a match, it would then check the date from the detained vessel against the date of the boarded vessel. If the dates corresponded, then we marked it with a value of 1 in the “detained” column for that vessel.

These four macros transformed the data into a format similar to the one shown below, in Figure 4. The parameters that were important to our study included Vessel Key, Vessel Name, Detained, Comparison (Deficiencies), Most Recent Boarding through Least Recent Boarding, Service, Cargo Type, and Moving Averages n = 2 through n = 10.

‘Detained’ is simply a binary value, zero if the vessel was not detained in the “comparison” boarding, and one if it was. Comparison is the number of deficiencies in the current boarding. This number will be used as a reference number, to determine if it is compliant or deficient.

In our sample data, we have omitted some columns due to a lack of space. However, the compliant vessels are notated in green, the deficient vessels are notated in yellow, and detained vessels are notated in red. The original data we received contained 36,158 boardings of 10,378 vessels. These boardings occurred over the time period of January 1, 1998 through December 31 of the year 2000. Our macros refined the data to 29,385 boardings of 5,980 vessels.

Next we took the moving average of the deficiencies, from the past n boardings (excluding the most recent boarding). We used different values of n, and displayed the results for all of these n values. We chose multiple n values because the length of the recent past affects how well the moving average measures performance. The most recent boarding is not used in the moving average because it was used as a measurement to compare the forecasting ability of deficiency history.

Using the moving average, we made graphs (Tables 2 and 3) to show the deficiency status of boarded vessels by different threshold values. The threshold value is used to eliminate the boardings of vessels that are likely to be compliant. This value is compared with the moving average. If the moving average is lower then the threshold, the boarding may be eliminated. We then analyzed this data to determine if any of the boarded, non-deficient vessels could be eliminated based on a particular threshold value. We tried to eliminate non-deficient vessels, while keeping the number of removed deficient vessels to a minimum, and without eliminating any vessels that were detained.

We then divided the data into sub-categories based on the service of the vessel. This included the groups freight ship, passenger ship, and tank ship. There were a few more vessel service types, such as school ship and research vessel, but we felt that there were not enough entries for these groups to accurately analyze these service types. We then reapplied our strategy, to see if the process was more efficient for certain service types of vessels, with the intent of creating specific threshold levels for each subgroup.

We have provided a hypothetical data set of boardings with random outcomes on deficiencies, as a simple example to show how we evaluated the actual data received from the Coast Guard. We have calculated the moving averages for $n = 2$ and $n = 3$. For a moving average of 2, the average consists of the 3^{rd} and 2^{nd} boardings. For an average based on the past 3 boardings, the average consists of the number of deficiencies from the 3^{rd}, 2^{nd}, and 1^{st} boardings.

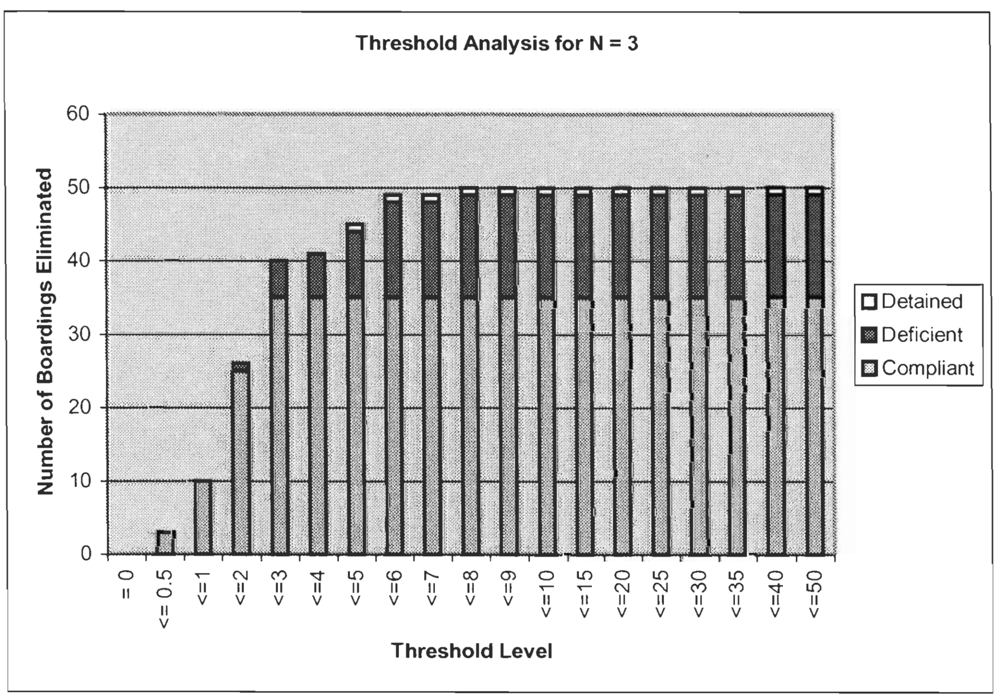
Figure 4: Hypothetical Data Set on the Number of Deficiencies

ey	Vessel Type	4th Boarding	3rd Boarding	2nd Boarding	1st Boarding	Moving Average (n=3)	Moving Average (n=2)
26	O	0	0	0	1	0.33	0.00
31	O	0	1	0	0	0.33	0.50
24	P	0	0	0	1	0.33	0.00
3	B	0	2	0	0	0.67	1.00
18	B	0	0	2	0	0.67	1.00
33	B	0	0	0	2	0.67	0.00
28	B	0	1	2	0	1.00	1.50
5	C	0	0	0	3	1.00	0.00
30	C	0	0	1	2	1.00	0.50
7	G	0	2	1	0	1.00	1.50
2	G	0	2	0	2	1.33	1.00
12	G	0	0	3	1	1.33	1.50
6	O	0	2	0	2	1.33	1.00
34	P	0	2	0	2	1.33	1.00
17	G	0	1	1	3	1.67	1.00
32	G	0	2	0	3	1.67	1.00
16	O	0	2	1	2	1.67	1.50
21	O	0	0	4	1	1.67	2.00
4	P	0	3	0	2	1.67	1.50
13	B	0	3	3	0	2.00	3.00
10	C	0	1	1	4	2.00	1.00
15	C	0	2	1	3	2.00	1.50
20	C	0	2	1	3	2.00	1.50
11	O	0	3	1	2	2.00	2.00
29	P	0	4	1	1	2.00	2.50
35	C	0	2	3	2	2.33	2.50
27	G	0	2	4	1	2.33	3.00
1	O	0	4	1	2	2.33	2.50
14	P	0	2	3	2	2.33	2.50
19	P	0	4	1	2	2.33	2.50
23	B	0	4	2	2	2.67	3.00
25	C	0	3	3	2	2.67	3.00
22	G	0	4	1	3	2.67	2.50
8	B	0	3	2	4	3.00	2.50
9	P	0	4	3	2	3.00	3.50
48	B	8	2	2	1	1.67	2.00
43	B	8	4	1	2	2.33	2.50
47	G	5	1	7	0	2.67	4.00
39	P	9	3	2	4	3.00	2.50
42	G	7	1	2	6	3.00	1.50
38	B	7	3	7	1	3.67	5.00
45	C	8	0	4	9	4.33	2.00
40	C	5	2	5	7	4.67	3.50
36	O	5	1	6	8	5.00	3.50
41	O	3	7	0	9	5.33	3.50
44	P	5	7	2	8	5.67	4.50
49	P	6	3	8	6	5.67	5.50
37	G	2	9	8	1	6.00	8.50
46	O	7	9	8	7	8.00	8.50
50	C	9	8	4	1	4.33	6.00

From that data we have constructed graphs to determine a possible "cutoff" value for the mean average. That is, a value that eliminates the maximum amount of unnecessary boardings without removing any detentions and minimizing the deficiencies lost.

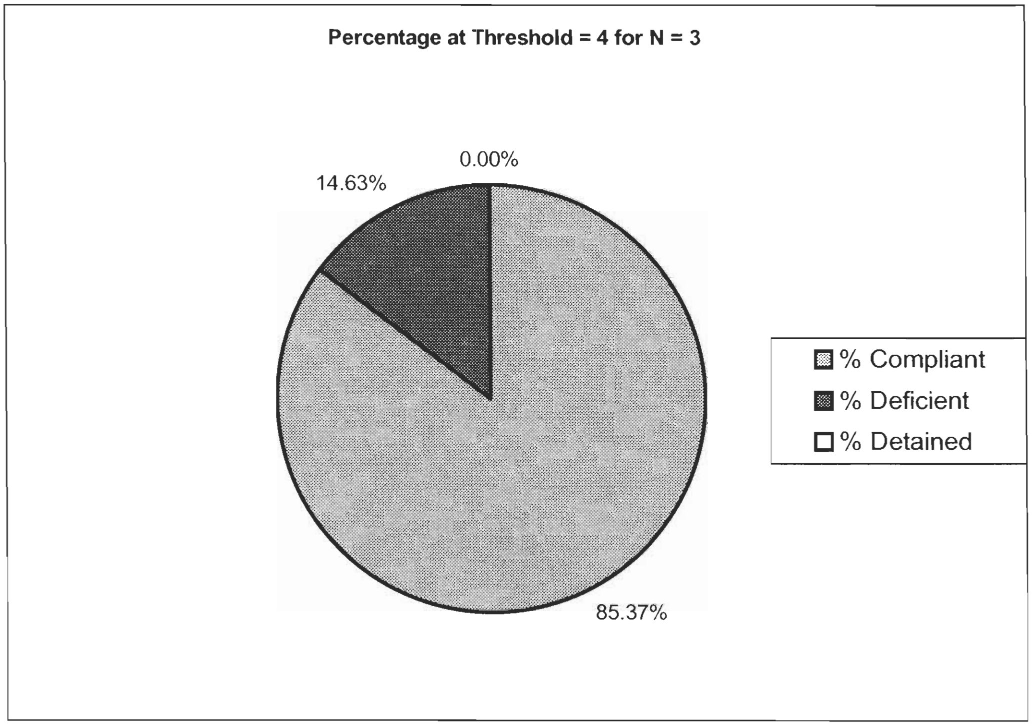
As shown in the graph below (Figure 5), a threshold value of 1 would eliminate 10 unnecessary boardings from our hypothetical data. If these 10 boardings were not performed, 160 man-hours would be saved. Increasing the threshold to 2 would increase savings to 25 boardings, which is equivalent to 400 man-hours. However, one deficient vessel would pass through port without inspection.

Figure 5: Hypothetical Threshold Analysis for N = 3



We have also constructed pie charts (Figure 6), for what we consider to be optimal threshold values for each value of *n*. These charts show the percentage of compliant, deficient, and detained vessels at the specific threshold.

Figure 6: Hypothetical Percentage at Threshold 4 for N = 3



By evaluating the graphs and data sets we have reported the outcomes and have a good idea which threshold value is the best at eliminating compliant vessels while keeping the number of deficient vessels eliminated low and not eliminating any vessels with controls.

V. DATA & ANALYSIS

The data we received and then arranged for our use is located in the 'Boardings_Final' worksheet of the Data-Final Excel spreadsheet we have also included. The analysis for all the boardings is in the 'Chart' worksheet. The additional worksheets are for the individual types of service vessels, with their analysis in the corresponding worksheets.

ALL SERVICE TYPES

The results displayed in Figure 7 apply to all of the service types we evaluated. This includes 36,158 boardings of 10,378 vessels between the years 1998 and 2000. The *n* value in Figure 7 refers to the number of values used when computing the moving average. The threshold listed in the table is the optimal threshold value we observed for a particular *n* value. That is, a threshold value that eliminates the highest number of compliant vessels while eliminating the minimum number of detained vessels.

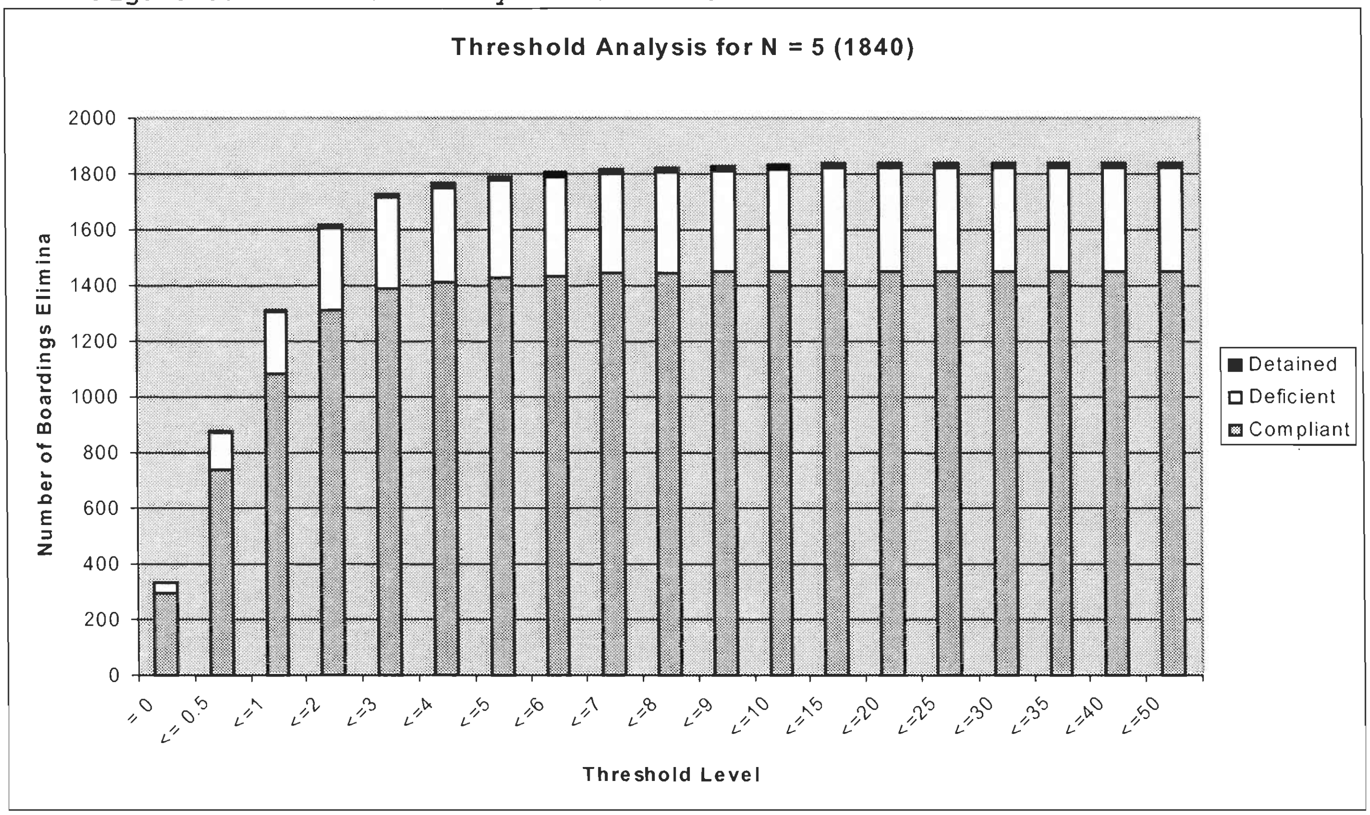
Figure 7: Optimal Threshold Values for all service types.

N Value	Threshold	Eliminated	Compliant	% Compliant	Deficient	% Deficient	Detained	% Detained
2	= 0	2831	2263	79.94%	554	19.57%	14	0.49%
3	= 0	1398	1172	83.83%	220	15.74%	6	0.43%
4	= 0	643	546	84.91%	95	14.77%	2	0.31%
5	= 0	332	294	88.55%	38	11.45%	0	0.00%
6	= 0	152	136	89.47%	16	10.53%	0	0.00%
7	<= 0.5	271	234	86.35%	37	13.65%	0	0.00%
8	<= 0.5	183	163	89.07%	20	10.93%	0	0.00%
9	<= 0.5	93	83	89.25%	10	10.75%	0	0.00%
10	<= 0.5	46	41	89.13%	5	10.87%	0	0.00%

As you can see from Figure 7, when there are at least five historical boardings for a vessel, that vessel can be eliminated from being boarded as long as there have been no deficiencies in its past. Out of a total of 5980 vessels included in our study, only 332 are eliminated using an *n* value of five and threshold of zero. This is much less then the 2831 eliminated with an *n* value of two. However, there is much less risk associated at the higher N value.

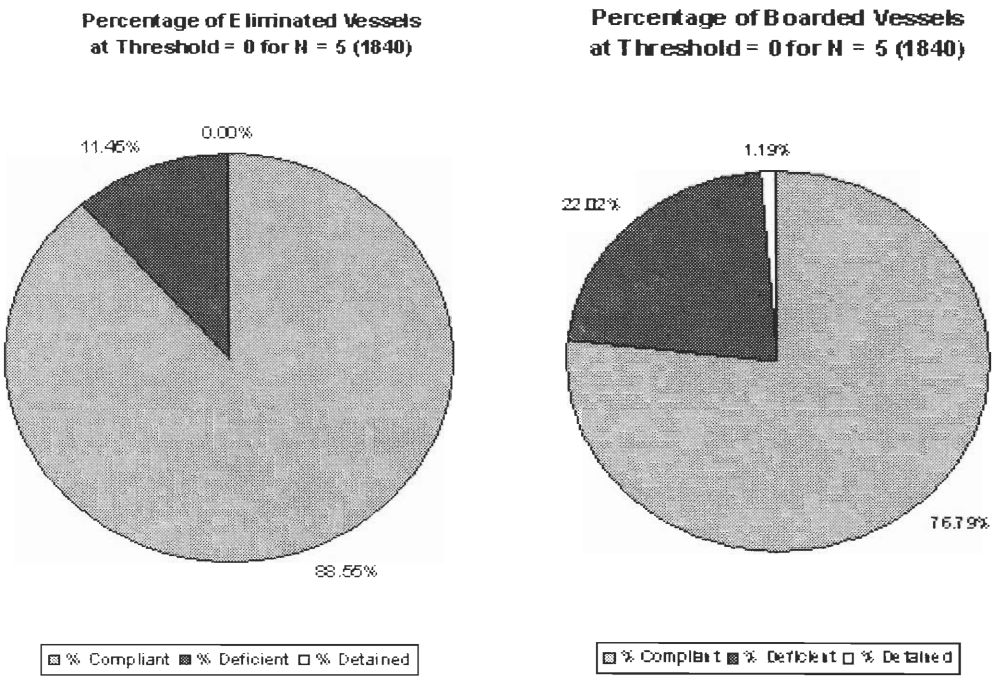
The following bar chart (Figure 8) displays the various possible thresholds at the optimal *n* value of five. At each threshold, there are a significant number of compliant vessels that can be removed from inspection, shown in blue. The black bands at the tops of some bars indicate the detentions that would be lost. At lower thresholds, fewer boardings are removed. As the threshold increases, more boardings are eliminated, but so are more detentions.

Figure 8: Threshold Analysis for *n* = 5



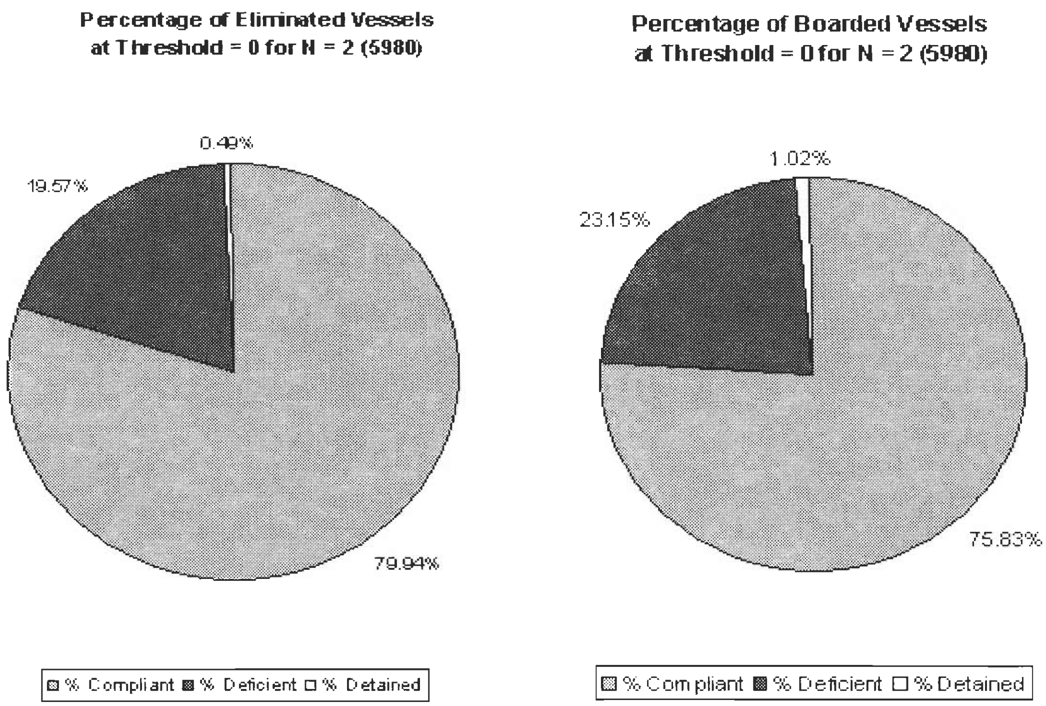
The two pie charts in Figure 9 display a direct comparison of the eliminated vessels versus the number of vessels that would still be boarded at the 0 threshold for a 5-term moving average. Notice that no detentions would be eliminated, and that 22% that would still be inspected are deficient, which is 332 vessels.

Figure 9: Percentage of Vessels at Threshold = 0 for *n* = 5



To contrast the previous comparison, we have included similar pie charts for the 2-term moving average (Figure 10). Notice that at even the lowest threshold of 0, 14 detained vessels would slip through. Yet 2,263 compliant vessel boardings would be eliminated. On the inspection side, 32 detentions would occur, and 2,388 compliant vessels would be inspected.

Figure 10: Percentage of Vessels at Threshold = 0 for n = 2



FREIGHT VESSELS

The table in Appendix B1 represents the key data that we observed strictly from the freight service vessels. It corresponds very closely to the data of all service types. At a threshold of zero with five historical boardings we are still able to avoid eliminating any detained vessels.

Again we have the threshold analysis and pie charts for the optimal threshold, with only freight vessels this time. These are also included in Appendix B.

TANK VESSELS

The results from the tank service vessel are listed in Appendix B2. Again, at an N value of five, there are no detained vessels that are eliminated. We are able to increase the threshold to 0.5, however. This eliminates more complaints vessels than a threshold of simply zero.

The threshold analysis and pie charts are included in Appendix B.

PASSENGER VESSELS

Appendix B also displays the results from the passenger service vessels. This service type is dramatically different than the other two service types. Most notably is the lack of any detained vessels. When presenting this data to Lieutenant Commander Scott Kuhaneck he informed our project team that the passenger vessels are subject to stricter regulations. Also, there would be direct financial and image related consequences against a passenger vessel if it were to be detained. This results in them being better suited for inspection, leading to very few or no detainments. We decided to include these vessels in our study anyway, in order to observe the variation between different service types. At an N value of two with a threshold of zero there are no detained vessels and very few vessels with deficiencies. While eliminating less compliant vessels, a threshold of one at an N value of four results in no detained or deficient vessels being eliminated.

A complete listing of the data and our results can be found in the Excel workbook in Appendix C. There is a master worksheet "Boardings_Final" that contains the details for all boardings. The boardings are then broken down into individual worksheets by vessel service type.

Each of these worksheets has a corresponding Chart worksheet that contains all iterations of the thresholds. There are nine tables on each worksheet. Each of these tables lists the nineteen thresholds for each of the nine *n*-term moving averages. Each table contains the total population size in its header row. This is the number of vessels that been boarded as many times as the number of terms in that particular moving average.

The table lists the total number of vessels that would be eliminated from inspection at each threshold. This number is then broken down by which vessels are compliant, deficient, or detained.

Three charts are associated with each moving average. Each Threshold Analysis bar chart graphically displays the information from the table. The boardings that would be eliminated by each threshold are broken down by compliance status. The first pie chart shows the eliminated vessels at a particular threshold. There are many thresholds, and creating two pie charts for each was impractical. Therefore we chose what we felt was the optimal threshold, based on the notion of acceptable risk discussed previously. The second pie chart is the converse of the first. It displays the compliance status of vessels that would still be inspected.

VII. CONCLUSIONS

From our study, we have found that historical boardings are a useful indicator of current performance. Our project team believes that this information can be used in order to save the United States Coast Guard resources by allowing an increased percentage of vessels to pass without inspection. Allowing vessels that have had no deficiencies in their past five boardings to pass resulted in eliminating the most compliant, while it also eliminated a large number of detained vessels. We were able to find a balance between eliminating a large number of compliant vessels while minimizing risk.

In light of the attacks of September 11, we live in a state of heightened security. Our recommendations were designed to minimize risk. Should the Coast Guard implement these changes, the thresholds that lose zero detentions will still maintain high security standards.

While presenting our results to LTCD Scott Kuhaneck of the Coast Guard we suggested that if a vessel had five historical boardings without any deficiencies, inspection could be deferred with very low risk. Of all the vessels we analyzed, there was not a single instance where a vessel that met this condition was detained. While a lower number of previous boardings (our *n* value) could have resulted in more eliminations, it would have increased the risk of letting a detained vessel slip by. We felt that less risk was more important than eliminating a greater number of vessels.

LTCD Kuhaneck may use our results in an attempt to revive the Qualship 21 project. Qualship 21 is a Coast Guard program intended to reward satisfactorily performing vessels. Traditionally, all vessels would be inspected at least annually. Qualship 21 allows eligible vessels some leeway in the inspection process (Qualship 21 Frequently Asked Questions).

There are several requirements. A vessel's history must be clear of detentions for the past three years. It must not have been involved in any serious casualties or violations. The last boarding inspection must have resulted in compliance. Owners and operators of vessels detained in the past two years are disqualified. The class society and flag state must also be acceptable under similar rules as in the targeting matrix (Qualship 21 Frequently Asked Questions).

With our results, the Coast Guard may be able to change these conditions. Instead of relying on detentions within the last three years, it may require that the vessel possessed no deficiencies within its last five boardings.

This would then give the vessel immunity from inspections for a set period of time.

There are various benefits awarded in this program depending on vessel service type. Freight vessels will enjoy two years without annual exams. Tankers will receive a less exhaustive inspection. Passenger vessels are not eligible for the program due to the safety risk.

This program was to begin on January 1, 2001, but for administrative reasons, it was delayed. It is our hope that our analysis will give sufficient support to revive this beneficial initiative (Qualship 21 Frequently Asked Questions).

Any changes the Coast Guard may make to their boarding system will require the notification of participating MOUs. The foreign authorities need to be kept apprised of the manner in which their ships will be inspected. We do not anticipate any complications from foreign countries because these revisions will not punish any vessels. They will only reward well-performing vessels.

Currently, Coast Guard officers are able to access vessel history information through the same Marine Safety Information System (MSIS) database from which we obtained our data. Officers must manually evaluate this information according to the Targeting Matrix.

We propose the Coast Guard invest in an information technology system that automates data storage and retrieval. When a vessel is scheduled to enter port, an officer can retrieve full vessel history, including deficiencies, needing only the vessel identification number. The system will automatically apply the traditional Targeting Matrix and then apply our deficiency filter system. If a vessel has no deficiencies in the five most recent boardings, our filter system may overturn a boarding request by the Targeting Matrix. The database system will consolidate all information, including a boarding decision, into a single report that the officer can review.

This system would have associated costs. Financially, each port would require a database client to allow the officers to query each vessel's history and details. This client would connect to the master MSIS database in Washington, D.C. While portions of this client system may already be in place, a program that shows deficiency history would need to be developed. The most significant cost is the loss of detainable vessels. We evaluated several different numbers of historical values when calculating the moving average along with different "cutoff," or threshold values of the moving average to determine the single best combination. Our goal was to preserve sensitivity while increasing specificity.

The benefits of this system outweigh the costs. By reducing the number of inspections conducted, the Coast Guard will save manpower resources. With their reduced funding, the potential for saving sixteen man-hours for each unnecessary boarding will counter any financial costs of implementing our recommendations. The system will also save time by automatically producing boarding decision reports.

Owners of vessels that have been recognized as eligible for Qualship 21 can use this distinction as a promotional item. When bidding for customers, either passengers or cargo shipments, this recognition can distinguish them from competitors. An additional benefit that may arise from revising the boarding system is improved foreign relations. Some of the emphasis is moved from targeted flag states to individual vessel history. These foreign countries will be pleased that their vessels are traveling uninterrupted through ports.

Through our analysis, we have shown deficiency history to be a valid predictor of future vessel performance. This information may be applied to optimize use of Coast Guard resources. It will allow them to reduce unnecessary boardings while maintaining the current security level.

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APPENDIX A: MACROS

1. RemoveLess

```
'Macro to remove vessel entries with less than 3 boardings.

Sub RemoveLess()

' Sort data by column vkey
Selection.Sort Key1:=Range("B2"), Order1:=xlAscending, Header:=xlGuess,
_ OrderCustom:=1, MatchCase:=False, Orientation:=xlTopToBottom

' Counter is the number of boardings per vessel
Dim counter As Integer
counter = 1

' x is the number of vertical rows
Dim x As Integer
x = 2

' Loop as long as there is a value for vkey
Do While Not Range("B" & x).Value = ""
    ' Check to see if two adjacent vkeys match
    If Range("B" & x).Value = Range("B" & (x + 1)).Value Then
            counter = counter + 1
            x = x + 1
    Else           'If the vkeys are different
      ' If there has been only 1 boarding for this vessel
        If counter = 1 Then
      ' select entire record for this vessel
            Rows(x & ":" & x).Select
            Selection.Delete Shift:=xlUp  ' delete the record
            counter = 1
        End If
      ' If there has been only 2 boardings for this vessel
        If counter = 2 Then
            x = x - 1
      ' Return to the first record for this vessel
            Rows(x & ":" & x).Select
            Selection.Delete Shift:=xlUp    ' Delete first record
            Rows(x & ":" & x).Select
            Selection.Delete Shift:=xlUp    ' Delete second record
            counter = 1
        End If
      ' If there has been 3 or more boardings for this vessel
        If counter >= 3 Then
            x = x + 1                    ' do not delete anything
            counter = 1
        End If
    End If
Loop

End Sub
```

2. RemoveMore

```
' Macro to remove vessel entries with more than 11 boardings

Sub RemoveMore()

' Sort data by column vkey, then by activity date
Selection.Sort Key1:=Range("B2"), Order1:=xlAscending,
Key2:=Range("E2") _, Order2:=xlDescending, Header:=xlGuess,
OrderCustom:=1, MatchCase:= _ False, Orientation:=xlTopToBottom

' counter is the number of boardings per vessel
Dim counter As Integer
counter = 1

' x is the number of vertical rows
Dim x As Integer
x = 2

' excess is the number of records past 11
Dim excess As Integer
excess = 0

' Loop as long as there is a value for vkey
Do While Not Range("B" & x).Value = ""
    ' Check to see if two adjacent vkeys match
    If Range("B" & x).Value = Range("B" & (x + 1)).Value Then
            counter = counter + 1
            x = x + 1
   Else
       ` Do not delete if 11 or less records exist
        If counter <= 11 Then
            counter = 1
            x = x + 1
        Else
            excess = counter - 11
            x = x - (excess - 1)
            Rows(x & ":" & x).Select

            Do While Not excess = 0
                Selection.Delete Shift:=xlUp
                excess = excess - 1
            Loop
            counter = 1
        End If
    End If
Loop

End Sub
```

3. Merge

```
Sub Merge()

Dim counter As Integer
Dim x As Integer
x = 2
counter = 1

Selection.Sort Key1:=Range("B2"), Order1:=xlAscending,
Key2:=Range("E2") _, Order2:=xlDescending, Header:=xlGuess,
OrderCustom:=1, MatchCase:= _False, Orientation:=xlTopToBottom

Do While Not Range("B" & x).Value = ""
    If Range("B" & x).Value = Range("B" & (x + 1)).Value Then
        counter = counter + 1
        If counter = 2 Then
            Range("H" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 3 Then
            Range("I" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 4 Then
            Range("J" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 5 Then
            Range("K" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 6 Then
            Range("L" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 7 Then
            Range("M" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 8 Then
            Range("N" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 9 Then
            Range("O" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
```

```
        End If
        If counter = 10 Then
            Range("P" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
        If counter = 11 Then
            Range("Q" & x).Value = Range("G" & (x + 1)).Value
            Rows((x + 1) & ":" & (x + 1)).Select
            Selection.Delete Shift:=xlUp
        End If
    Else
        x = x + 1
        counter = 1
    End If
Loop

End Sub
```

4. Detained

```
Sub Detained()

' Macro to add records from "Detentions - Final.xls" to our spreadsheet

Dim x As Integer    'Vertical row counter for controlled
x = 2

' Loop as long as there is a vkey value in cell B350, which is the
' beginnning of the list of detained vessels from "Detentions -
' Final.xls"
Do While Not Range("B350").Value = ""
    ' Loop as long as there is a vkey value in current record of
    ' controlled vessels from "Boardings - Final.xls"
    Do While Not Range("B" & x).Value = ""
        ' If vkey from detained matches vkey from controlled, then ships
        ' match
         If Range("B350").Value = Range("B" & x).Value Then
             ' And if the activity dates match
             If Range("E350").Value = Range("E" & x).Value Then
                 ' Then mark this record as detained
                 Range("F" & x).Value = 1
             End If
         End If
         ' Advance to next record in detentions
      x = x + 1
Loop

      ' Starts checking for next detained vessel at the

beginning of the

      ' controlled
```

```
      x = 2

    Rows("350:350").Select
    ' Deletes detentions already checked
    Selection.Delete Shift:=xlUp
Loop

End Sub
```

APPENDIX B: VESSEL TYPE CHARTS

Figure 11: N-values and Thresholds for All Vessels

N Value	Threshold	Eliminated	Compliant	% Compliant	Deficient	% Deficient	Detained	% Detained
2	= 0	2055	1627	79.17%	419	20.39%	9	0.44%
3	= 0	987	820	83.08%	162	16.41%	5	0.51%
4	= 0	451	384	85.14%	66	14.63%	1	0.22%
5	= 0	227	202	88.99%	25	11.01%	0	0.00%
6	= 0	97	88	90.72%	9	9.28%	0	0.00%
7	<= 0.5	168	144	85.71%	24	14.29%	0	0.00%
8	<= 0.5	105	93	88.57%	12	11.43%	0	0.00%
9	<= 0.5	49	42	85.71%	7	14.29%	0	0.00%
10	<= 0.5	20	17	85.00%	3	15.00%	0	0.00%

Figure 12: Threshold Analysis for Freight Vessels

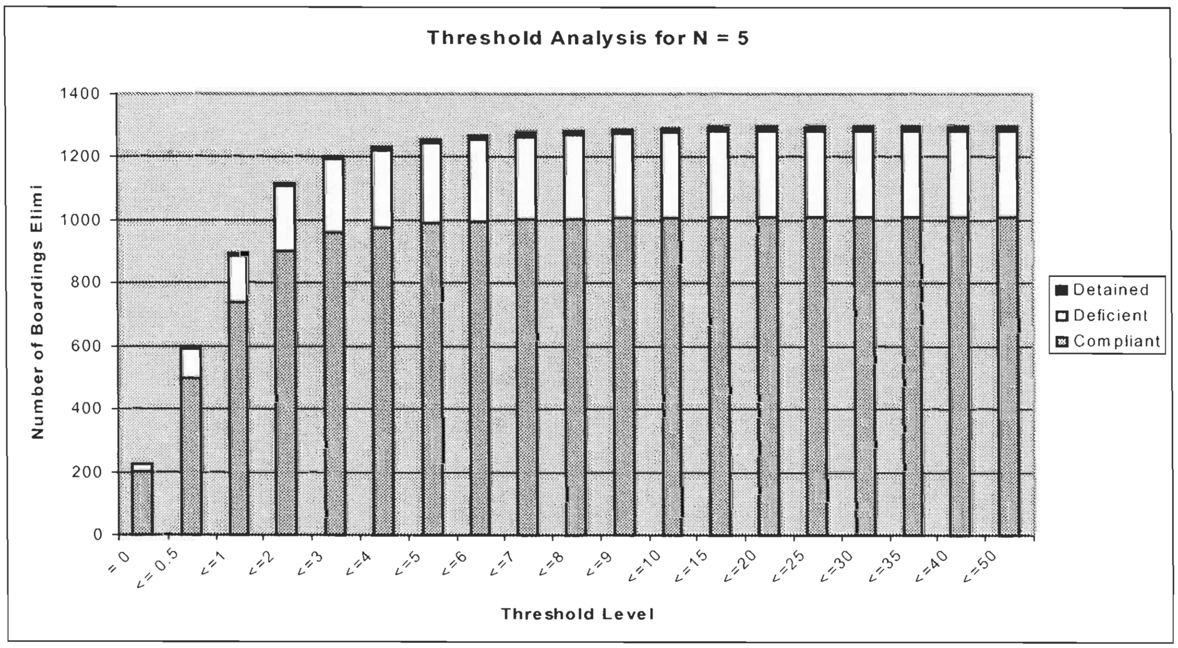
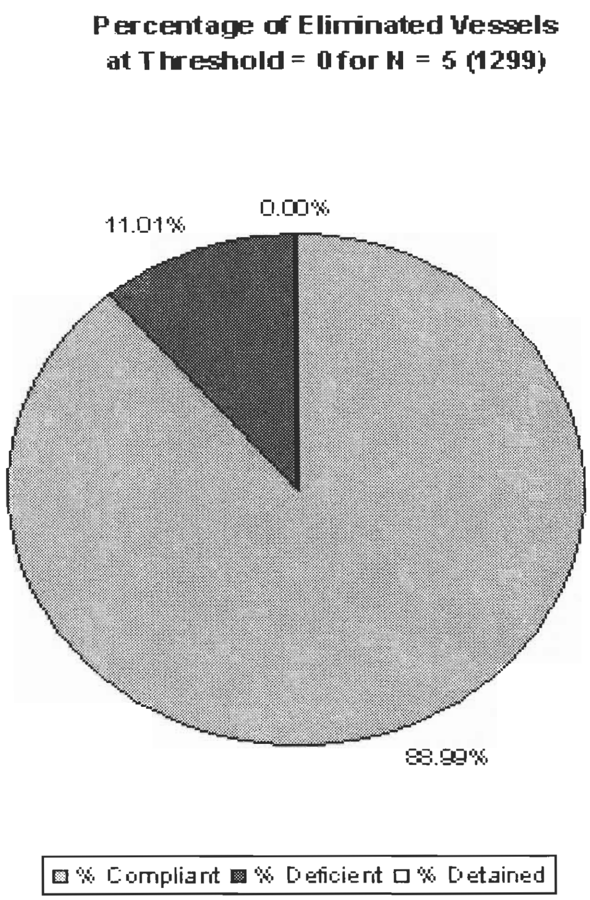


Figure 13: Freight Vessel Percentages



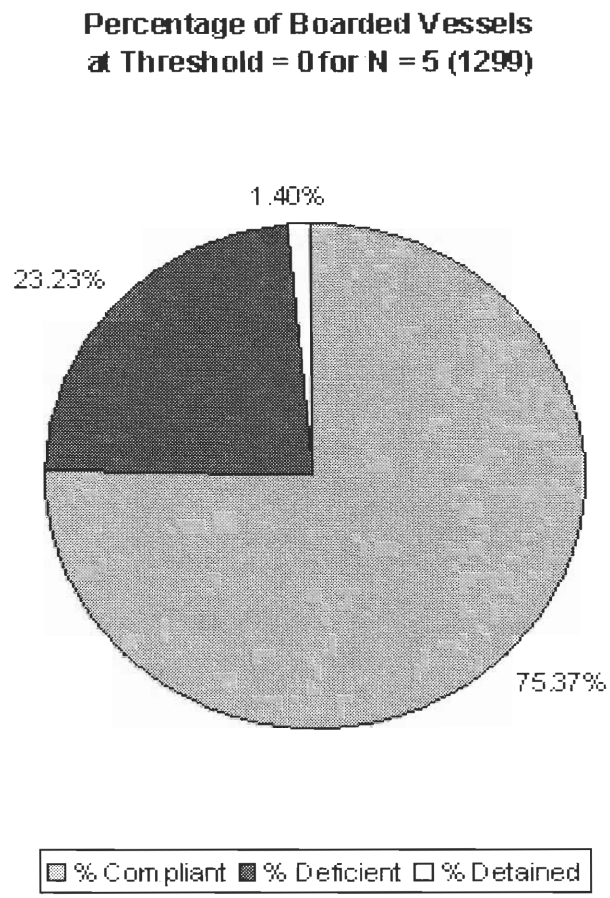


Figure 14: N-values and Thresholds for Tank Vessels

N Value	Threshold	Eliminated	Compliant	% Compliant	Deficient	% Deficient	Detained	% Detained
2	= 0	702	570	81.20%	127	18.09%	5	0.71%
3	= 0	375	316	84.27%	58	15.47%	1	0.27%
4	= 0	170	140	82.35%	29	17.06%	1	0.59%
5	<= 0.5	263	225	85.55%	38	14.45%	0	0.00%
6	= 0	48	41	85.42%	7	14.58%	0	0.00%
7	<=2	201	163	81.09%	38	18.91%	0	0.00%
8	<=3	143	121	84.62%	22	15.38%	0	0.00%
9	<=2	74	64	86.49%	10	13.51%	0	0.00%
10	<=2	42	37	88.10%	5	11.90%	0	0.00%

Figure 15: Threshold Analysis for Tank Vessels

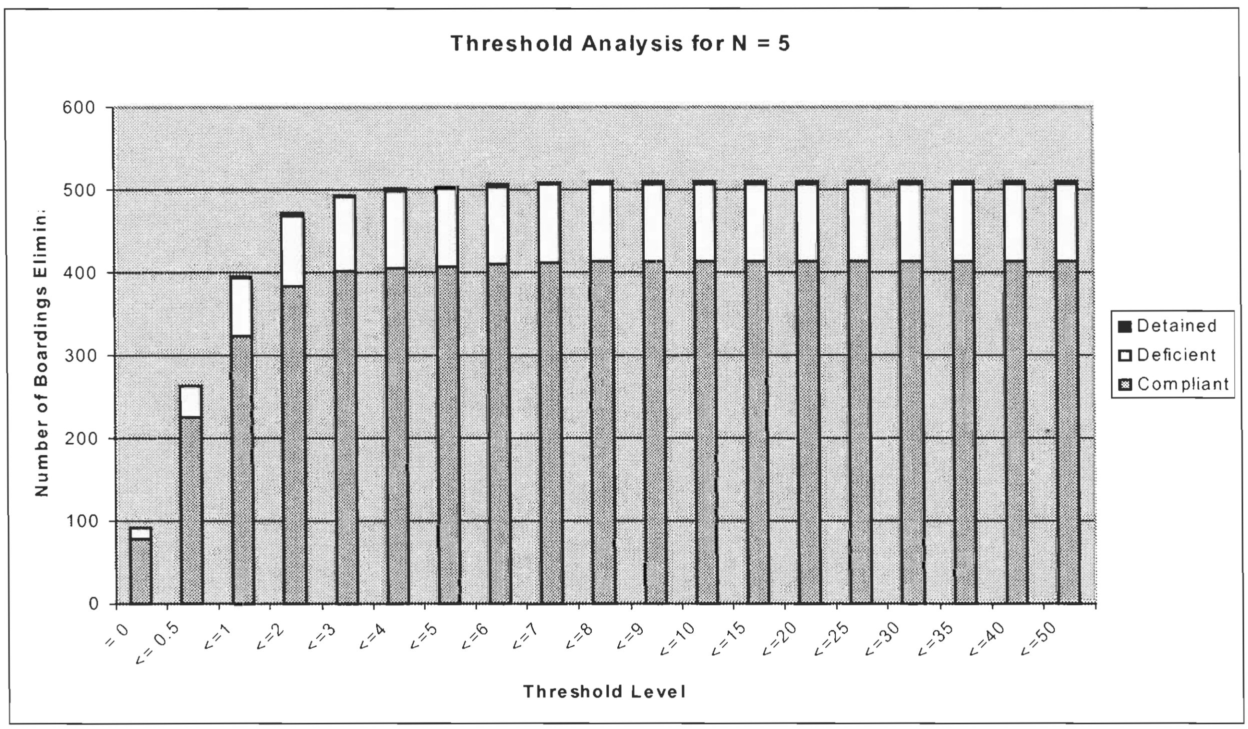
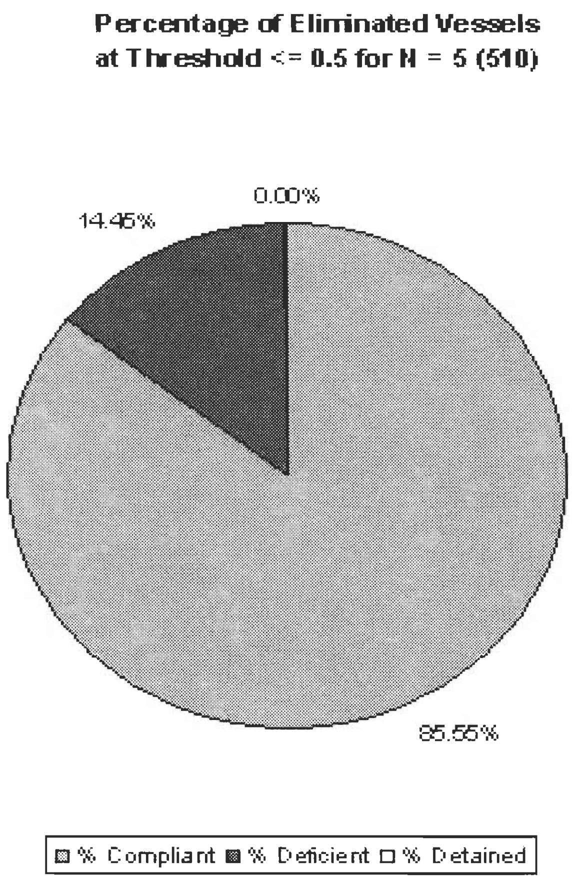


Figure 16: Tank Vessel Percentages



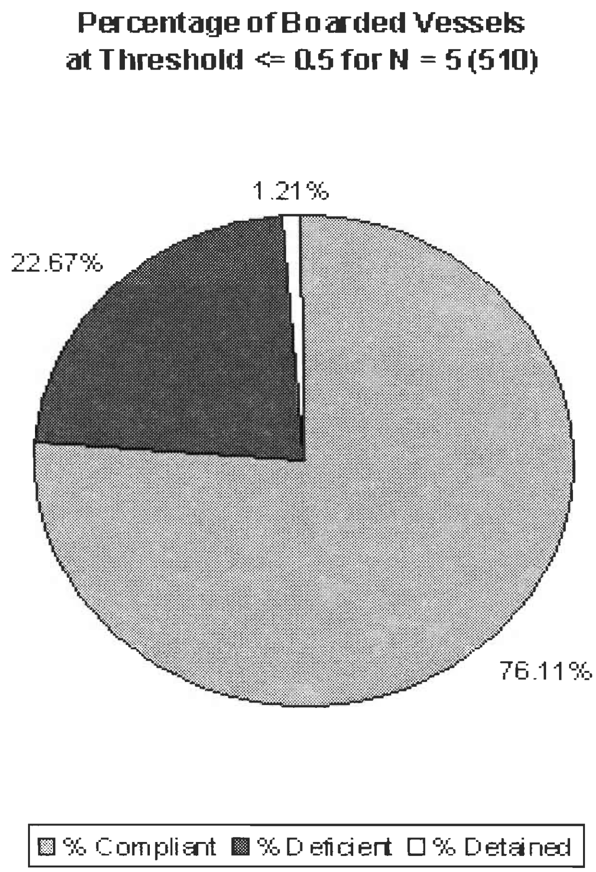


Figure 17: N-values and Threshold for Passenger Vessels

N Value	Threshold	Eliminated	Compliant	% Compliant	Deficient	% Deficient	Detained	% Detained
2	0	55	51	92.73%	4	7.27%	0	0.00%
3	<= 0.5	42	41	97.62%	1	2.38%	0	0.00%
4	<=1	33	33	100.00%	0	0.00%	0	0.00%
5	<=1	21	21	100.00%	0	0.00%	0	0.00%
6	<=1	15	15	100.00%	0	0.00%	0	0.00%
7	<=4 - <=50	17	17	100.00%	0	0.00%	0	0.00%
8	<=3 - <=50	15	15	100.00%	0	0.00%	0	0.00%
9	<=3 - <=50	14	14	100.00%	0	0.00%	0	0.00%
10	<=4 - <=50	13	13	100.00%	0	0.00%	0	0.00%

Figure 18: Threshold Analysis for Passenger Vessels

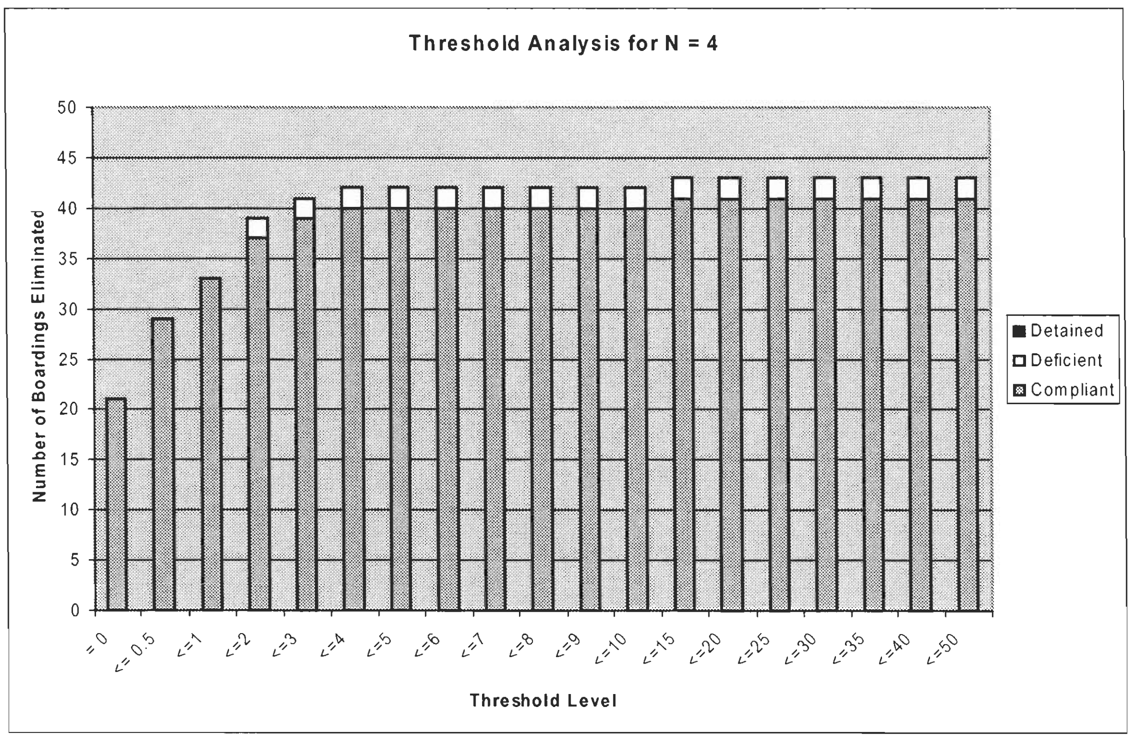
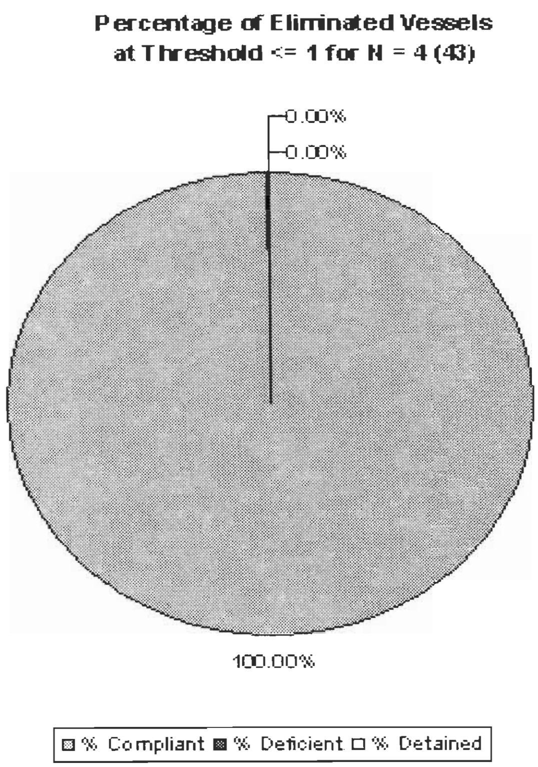
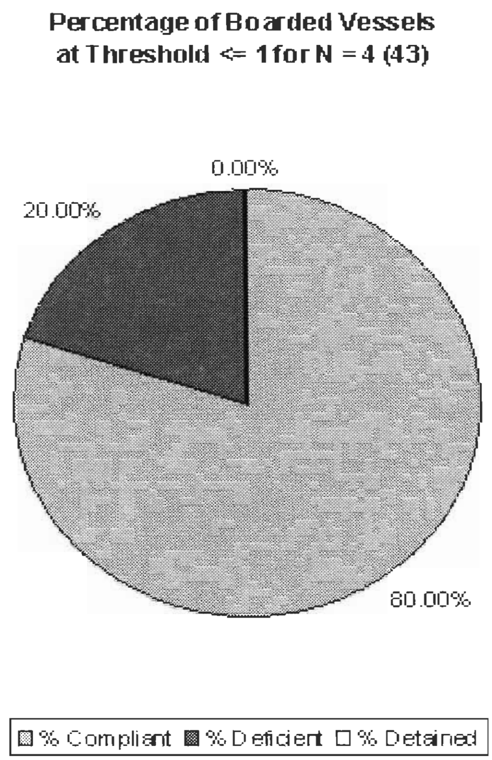


Figure 19: Passenger Vessel Percentages





APPENDIX C: ALL DATA AND ANALYSIS

See the file "Data-Final.xls" on the included compact disc for full details.