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Passenger Vessel Weight Measurement

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Degree of Bachelor of Science
by

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Abstract

The U.S. Coast Guard identified the problem of passenger vessels becoming overloaded due to increased passenger weight. Our project goal was to recommend an effective method that would allow vessel masters to know if their vessel has exceeded its maximum allowable weight. Through background research and interviews with people in the industry, we established twelve possible solutions to the problem. We recommended four solutions to help avoid passenger vessel overloading.

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Authorship

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Executive Summary

Factors contributing to the recent capsizing of passenger vessels in the United States have been associated with overloading. All passenger vessels in the United States have different weight limitations that are determined by the vessel type and size. When these limitations are exceeded, the vessel might become unstable, and the risk of capsizing increases. There have been two recent instances in the United States where passenger vessel overloading has been associated to vessel capsizing resulting in fatalities. In Baltimore Harbor, five passengers died when the passenger pontoon vessel ***Lady D*** capsized as a result of overloading, weather, and other factors (National Transportation Safety Board, 2004). In Lake George, New York, the passenger vessel ***Ethan Allen*** capsized, and twenty passengers died as a result of overloading and other factors (National Transportation Safety Board, 2006). Despite vessel loading restrictions, there is evidence that passenger vessels are becoming overloaded.

Passenger vessel masters have relied on the U.S. Coast Guard's weight regulations as a tool for determining whether their vessel is overloaded. The current regulations use an average passenger weight to determine the maximum number of passengers that should be allowed on a vessel (U.S. Coast Guard, 2008). The problem with this method is that the average weight of an American frequently changes (Centers For Disease Control, 2004). In the cases of the ***Lady D*** and ***Ethan Allen***, the vessel master thought that he was carrying less weight than was actually on the vessel. This indicated that the current regulations should be changed and more effective methods for determining if a vessel is overloaded should be implemented.

The goal of our project was to recommend an effective system that would allow passenger vessel masters to determine if their vessel is overloaded before they depart on a voyage. To obtain this goal, we analyzed the ***Lady D*** and ***Ethan Allen*** case studies of passenger vessel overloading. We also identified methods used for determining the stability of passenger vessels. In order to amass various possible solutions, we identified methods used by the Federal Aviation Administration for determining weight onboard aircraft as well as other methods for measuring weight and researched factors that affect vessel overloading. We also identified legal and privacy issues that might be associated with our possible solutions. To accomplish these objectives, we performed research and obtained expert opinions from naval architects and marine engineers from the U.S. Coast Guard. We also interviewed passenger vessel masters and company managers over the phone or at their facilities.

Based on information we gained from research and speaking with naval architects and engineers at the USCG, we formulated twelve different possible solutions to help avoid passenger vessels from becoming overloaded. These possible solutions were divided into three categories: weight estimation methods, average weight methods, and physical methods. The weight estimation methods we researched included asking passengers how much they weigh, using a number approximation method, estimating passengers' weight by size, and using load marks. The average weight methods we looked at were using an average weight of 185 pounds for all passengers, using average weights based on data from the National Health Statistics Report, using the standard average weights as the Federal Aviation Administration, and using segmented average weights from the Federal Aviation Administration. The physical methods we investigated included using calibrated scales, using a floating barge, relating a passengers' height with an average weight, and using a fulcrum that is a simplified weighing method.

We analyzed our twelve possible solutions based on efficiency, ease of implementation, enforceability, and accuracy. Efficiency, ease of implementation, and enforceability were analyzed qualitatively, while accuracy was analyzed quantitatively using loading simulations. Since the effectiveness of different possible solutions is dependent upon the size of the vessels, we analyzed accuracy for vessels carrying twenty-five, forty-nine, and 149 passengers.

We found the solution that is most efficient is the USCG Proposed Weight method since it does not require a lot of time to determine if the vessel is overloaded. Our solution that is easiest to implement is Asking Passengers their Weight since it can be implemented quickly and easily with little or no required cost. The solutions that we found to be most enforceable are CDC Weights, FAA Segmented Weights, and USCG Proposed Weight since they do not involve having to account for children. Using loading simulations, we determined that our most accurate solution for twenty-five and forty-nine passengers was using the Number Approximation. For 149 passengers, the most accurate solution was CDC Weights. These were the most accurate because each performed the best for the thirty simulations associated with each number of passengers.

After analyzing our results, we determined the most practical methods for allowing vessel masters to know if their vessel has surpassed its maximum allowable weight before it leaves on a voyage. Since passenger vessel companies and vessel's size vary, we have devised recommendations for vessels that carry twenty-five, forty-nine, and 149 passengers. For passenger vessels that carry twenty-five passengers, we recommend that the FAA Standard

Weights method is the best method. For vessels that carry forty-nine passengers, we recommend using the Number Approximations method. For larger vessels that can carry 149 passengers, we recommend that the best weight monitoring method that we analyzed was the proposed U.S. Coast Guard system that utilizes an average weight of 185 pounds per passenger.

As a result of our analysis, we also found that estimating weight based on a passenger’s height was very effective. This method calculates the total passenger weight near the actual passenger weight, but underestimated too often to be practical. We recommend that further research is done and an implementation method is devised so that this method can become a feasible solution.

1.0 Introduction

Businesses across the United States use passenger vessels for tours, fishing, diving excursions, dinner cruises, ferrying passengers from one location to another, and other activities. These vessels have weight limits associated with them that are determined by the vessel's type and size. When these weight limits are exceeded, the stability of that vessel may not be satisfactory. Without satisfactory stability, a passenger vessel is more prone to accidents.

Despite regulations put in place by the United States Coast Guard (USCG), there are still passenger vessels that have capsized. The factors that have contributed to these boat accidents are mainly captain's discretion, weather conditions, and overloading. The capsizing of the ***Lady D*** in Baltimore Harbor showed that overloading can be a factor in passenger vessel accidents. In this incident, the vessel had recently passed a safety inspection and was in compliance with all small passenger vessel regulations (Dresser, 2006). This event showed that despite vessel loading restrictions, there is evidence that passenger vessels are still becoming overloaded. To decrease the risk of accidents, the Coast Guard plans to improve loading standards on passenger vessels. To do this they want to implement an improved method that vessel masters could use to determine whether their boat is overloaded before they depart on a voyage.

Passenger vessel masters have relied on the U.S. Coast Guard's weight regulations as a tool for determining whether if their vessel is overloaded. The current regulations use an average passenger weight to determine the maximum number of passengers that should be allowed on a vessel (U.S. Coast Guard, 2008). The problem with this method is that the average weight of an American frequently changes (Centers For Disease Control, 2004). Passengers are also carrying different amounts of luggage. This additional weight is not accounted for when calculating how much weight is being loaded onto a vessel. As a result, there is a chance that a situation will occur when all or most of the passengers onboard the vessel weigh more than the average weight used in Coast Guard regulations resulting in an undesirable loading condition.

The United States Coast Guard and the Society of Naval Architects and Marine Engineers (SNAME) have studied passenger vessel overloading in the United States. They have analyzed different instances of vessel overloading and have made proposals to adjust the current U.S. Coast Guard regulations to make passenger vessels safer. They have determined that there may be improved methods for determining weight on passenger vessels. However, there has not been any research done to determine what methods are practical. The U.S. Coast Guard is interested in finding other methods that could be implemented to ensure that passenger vessel overloading will not become a problem in the future.

Our project’s goal was to recommend an effective system that would allow passenger vessel masters to determine if their vessel is overloaded before they depart on a voyage. To obtain this goal, we identified and analyzed recent case studies of passenger vessel overloading. We also identified methods used for determining the stability of passenger vessels. In order to amass various possible solutions, we identified methods used by the Federal Aviation Administration for determining weight onboard aircraft as well as other methods for measuring weight and researched factors that affect vessel overloading. We also identified some legal or privacy issues that might be associated with our possible solutions. To accomplish these objectives, we performed research and obtained expert opinions from naval architects and marine engineers from the U.S. Coast Guard. We also interviewed passenger vessel masters and company managers over the phone and by visiting their facilities. We then used the criteria of efficiency, ease of implementation, enforceability, and accuracy to analyze several possible solutions to select our proposed solution. As a result of our work, we recommended solutions to prevent passenger vessels in the United States from becoming overloaded by providing vessel masters with a method for verifying that their vessel is not overloaded before they depart on a voyage. We expect that the implementation of our recommendations will result in fewer vessel accidents and thus fewer passenger casualties.

2.0 Background

Standards and regulations regarding passenger vessel capacities have not been updated since the 1960's and have contributed to the capsizing of vessels and deaths of passengers. This has caused the United States Coast Guard to re-evaluate their standards and regulations for calculating passenger weight. In this chapter we provide descriptions of the vessels we are addressing and of the ***Lady D*** and ***Ethan Allen*** incidents that resulted in passenger fatalities. A summary of current Coast Guard regulations and a description of the Coast Guard's Proposed Rule are also provided. In order to show how drastically the average weight of an American has changed, demographic information from the Centers for Disease Control and Prevention are presented. We also provide information regarding how legal and privacy issues pertain to our project. In the last section of this chapter, research regarding possible solutions to our problem is also presented.

2.1 Background on Passenger Vessels

The passenger vessels that this report focused on were small passenger vessels that were classified by the Code of Federal Regulations as vessels of subchapter T (see Appendix C to understand the classification process). More specifically, the report focused on amphibious vessels, chartered fishing vessels, cruise vessels, diving vessels, excursion vessels, ferries, and water taxis. These vessels can be found all over the United States in lakes, bays, and oceans. They form a large part of American transportation and recreation.

Amphibious vehicles were first developed in the 1940's during World War II by both Axis and Allied forces. Their primary purpose was to transport supplies and equipment from supply ships offshore to fighting units onshore. Because the U.S. built so many (approximately 20,000), after the war many were retired (DUKW, 2008). Then in the late 1970's these amphibious vehicles found a new use as amphibious tour vessels (Ride the Duck, 2006). Commonly known today as "Duck Tours," these vessels can be seen across the United States giving city tours on land to excited guests and plunging into a nearby body of water as part of the tour. Amphibious vehicles have also recently become useful to the National Guard in rescue missions during devastating storms across the country (*Encyclopedia Britannia*, 2008).

When addressing fishing vessels, it is important to distinguish between commercial fishing vessels and chartered fishing vessels. A commercial fishing vessel can deal with both the catching and processing of fish. Chartered fishing vessels deal only with the catching of fish (Fishing Vessel, 2008). They range in size and capacity; however, in our research we have focused on chartered fishing vessels that carry between six and 150 passengers. Every year thousands of people use chartered fishing vessels as a means of recreation.

The term cruise ship or cruise vessel generally makes people think of large ocean liners that take a few thousand guests on a luxurious vacation. In this report, however, we focus on cruise vessels that carry up to 149 passengers. When looking at cruise vessels our investigation focused on river and harbor cruises, along with lunch and dinner cruises (Cruise Ship, 2008). Depending upon their purpose these vessels can vary in size. Also, depending upon their size and purpose, the weight of the passengers on some of these vessels may be negligible when compared to the total vessel weight. Good examples of this are dinner cruises. With so much other necessary equipment such as tables, chairs, galley equipment, etc, the added weight of the passengers may not be significant when compared to the added weight of this equipment.

Diving vessels are a bit different from most vessels seen on the water. This is because they require special equipment that the passengers need for diving. Usually diving vessels have a diving platform and multiple entrances onto the vessel to make diving easier, although this is not necessary or true for all diving vessels. These vessels carry diving equipment and have special storage for all of this equipment. They also have emergency equipment in case something goes wrong during a dive. These vessels vary in size and can have cabins if dive trips are intended to be overnight (Dive Vessel Profiles, 2008).

Although they can be easily confused with cruise vessels, excursion vessels are different. Cruise vessels generally take passengers on a longer voyage, whereas most excursion vessels tend to make shorter trips (generally about one to one and half hours) (Excursion, 2008). The main purpose of an excursion vessel is for tour, but they are also used for whale or dolphin watches. Excursion and amphibious vessels are very similar in purpose, but their main difference lies in the fact that excursion vessels operate only in the water. Because of their range of purposes, there are many in the United States.

Another type of passenger vessel that we researched was ferries. Ferries are a very common means of public transportation. Generally, ferries carry passengers, but some carry vehicles as well (Office of Federal Register National Archives and Records Administration, 2004). Ferries vary in size and therefore vary in stability. For larger ferries that carry vehicles, passenger weight is usually negligible in comparison to the weight of the vehicles. Therefore, passenger weight may not need to be considered when determining the stability of the vessel. Smaller ferries are more susceptible to overloading.

Water taxis are basically ferries with the main difference being that water taxis only carry passengers on short harbor or river routes (Water Taxi, 2008). They are generally smaller than ferries and are usually (but not always) pontoon boats. They can vary in size depending upon location and frequency of use. Water taxis are becoming a more popular form of public transportation across America.

There are many different types of passenger vessels used across the United States. Our research focused on seven different types of passenger vessels that are regulate under Subchapter T of Coast Guard regulations: amphibious vehicles, chartered fishing vessels, cruise vessels, diving vessels, excursion vessels, ferries, and water taxis. These vessels make up a wide variety of the purposes for which passenger vessels are used, and helped us look at different situations when a possible solution to weight overloading on vessels could be needed.

2.2 Case Studies

Recently in the United States overloading has been identifying as a contributing factor in the capsizing of two ferries: ***Lady D*** and ***Ethan Allen***. The ***Lady D*** was under U.S. Coast Guard regulations and the ***Ethan Allen*** was under New York State regulations, but both were loaded above their maximum allowable weight. The details of each of these accidents are presented in the following sections.

2.2.1 *Lady D*

On March 6, 2004, the passenger vessel ***Lady D***, pictured in Figure 2.1, left Fort McHenry, Maryland, with twenty-three passengers and two crew members onboard; however, before reaching its destination in Fells Point, Maryland, it ran into severe weather and capsized

(National Transportation Safety Board, 2006b). According to the NTSB's report on the ***Lady D*** accident, the probable cause of the accident was that the vessel's lack of intact stability, which was caused by an excessive number of people and an outdated average passenger weight, was unable to withstand the strong winds and waves. In a response to the NTSB's report, Rear Admiral Brian Salerno of the U.S. Coast Guard wrote a letter to Chairman Mark Rosenker of the NTSB. This letter stated that the probable cause of the accident was that "the operator disregarded the obvious indications of impending unreasonable conditions, namely severe weather, including thunder, lightening, approaching storm clouds, rain, wind and waves, while departing from the dock". These reports were similar when describing the major cause of the accident but drastically different when assigning blame for the accident.

Figure 2.1: Picture of the *Lady D* (National Transportation Safety Board, 2006b, p.3)

Of the twenty-three passengers aboard, there were three children under ten years old and twenty adults between the ages of twenty-three and sixty (National Transportation Safety

Board, 2006b). The ferry was carrying ten child-size and twenty-five adult-size lifejackets as was required by the ***Lady D***'s Certificate of Inspection (COI). The master of the ferry was radioed by the senior captain shortly after it left Fort McHenry to wait until the storm had blown through to begin the trip. However, once the senior captain was informed that the ferry had already departed, he advised the master to go to the Baltimore Marine Center or Henderson's Wharf.

The master tried to steer the ferry into Henderson's Wharf, but the wind quickly increased, so the master was unable to maneuver into the wharf (National Transportation Safety Board, 2006b). Within seconds of the wind and waves increasing in intensity, the ferry became very difficult to control and thus capsized. Figure 2.2 is a photograph of the ***Lady D*** the day after the accident without its deckhouse, which was damaged due to the harsh weather conditions. Some survivors told the NTSB that they were unable to open one of the two doors, while other survivors said that they were unable to open the closed windows. They resorted to escaping through the nearest already opened window.

Figure 2.2: ***Lady D*** without Its Deckhouse (National Transportation Safety Board, 2006b, p.17)

Rescue teams were at the scene of the accident within ten minutes to help people out of the cold water, and the rescue boat was also able to lift the ***Lady D*** partway out of the water so that two adults and a young girl were able to escape the ferry. Table 2.1 describes the injuries induced by the capsizing. The causes of death were all drowning complicated by hypothermia; the water temperature was 44 degrees Fahrenheit.

Table 2.1: Injuries Caused by the Capsizing of the *Lady D* (National Transportation Safety Board, 2006b, p.7)

Injury Type	Crew	Passengers	Total
Fatal	0	5	5
Serious	0	4	4
Minor	2	10	12
None	0	4	4
Total	2	23	25

Before any passenger vessel is allowed to transport people, the U.S. Coast Guard must determine how many crew members are required to be on each trip. They take into account many different aspects of the passenger vessel such as “the size of the vessel, its route, the type and horsepower of the vessel’s propulsion machinery, the number of passengers the vessel may carry, the type and location of lifesaving equipment installed on the vessel, and the hazards specific to the route and service” (National Transportation Safety Board, 2006b, p.8). The ***Lady D*** was required to have one crew member but the ***Lady D*** normally had two crew members: a licensed master and an unlicensed mate.

The ***Lady D*** was certificated on March 18, 1996, for the Baltimore Harbor Shuttle, LLC. (National Transportation Safety Board, 2006b). It was permitted to be sistered to a previous ferry; the ***Lady D*** was thirty-six feet long and eight feet wide. The first two ferries were built with open sides in the deckhouse and had no windows, while the last two were built with glass windows.

In 1992, the first of the four ferries, Fells Point Princess, passed its SST that included elements from both the SST regulations and the U.S. Coast Guard Marine Safety Manual (MSM) pontoon vessel guidance (National Transportation Safety Board, 2006b). The inspector made a mistake when he did not move the weights to the extreme outboard and then take the measurements. The NTSB report stated that the ***Lady D***’s passenger capacity was based on the safety test that the Fells Point Princess underwent, which was inappropriate for that vessel. In Rear Admiral Salerno’s letter to the NTSB, the U.S. Coast Guard said that the ***Lady D*** was not inaccurately certificated because it complied with all intact stability regulations in 46 CFR Subchapter S.

Before the accident, when underway, the criteria that required masters to bring their ferries into a port are as the company's fleet director said, "when visibility was 'dramatically reduced', when lightning was in the immediate area, or when the wind was over thirty to thirty-five knots, depending on the operating route" (National Transportation Safety Board, 2006b, p.23). Following the accident, each ferry in Baltimore Harbor was given specific standards for deciding when it was safe to embark on a trip. Table 2.2 shows the new standards for specific ferries.

Table 2.2: New Standards Set for Specific Ferries in Baltimore Harbor (National Transportation Safety Board, 2006b, p.24)

Boat	Sustained Winds (mph)	Wind Gusts (mph)*	Sea State (feet)
Raven*	30	35	2
Phoenix	30	35	2
Migeni	30	35	2
Patrick Duffy	25	30	2
Eagle	25	30	2
*Wind gusts lasting 15 seconds or longer			

After the accident was reviewed, the NTSB said that the ***Lady D*** should have only been allowed to carry fourteen passengers at the standard average weight of 140 pounds (National Transportation Safety Board, 2006b, p55). Interviewing passengers and examining the medical records revealed to the NTSB that the average passenger weight on the ***Lady D*** was 168 pounds. The ferry was allowed to carry up to 1,960 pounds, but it was actually carrying 4,200 pounds, which is 2,240 pounds more than regulated.

In Rear Admiral Salerno's response letter to the NTSB, the U.S. Coast Guard stated that the ***Lady D*** was permitted to carry twenty-five passengers at 140 pounds. As was acknowledged before, the ***Lady D*** was in compliance with all applicable intact stability requirements. Thus, the ***Lady D*** was certificated to carry 3,500 pounds, but the ferry was still overloaded by 700 pounds.

Figure 2.3 explains that the ***Lady D***'s maximum heeling moment would have been thirty-three degrees under normal weather conditions before it would have been unable to recover and thus capsize. On the day of the accident, due to the poor weather conditions, the ferry's maximum heeling moment was only twenty-two degrees.

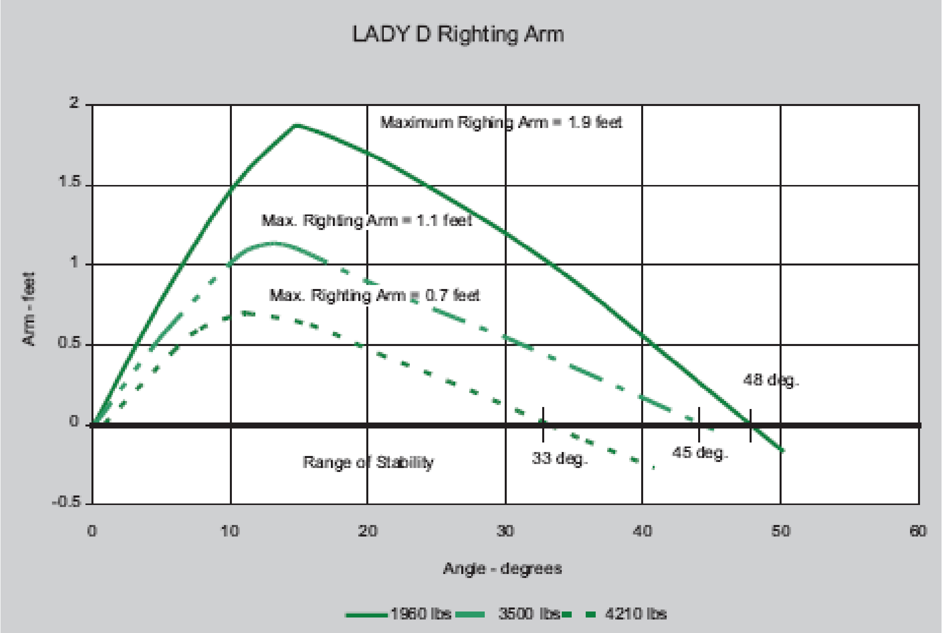


Figure 2.3: ***Lady D's*** **Maximum Heeling Moment under Good Weather Conditions (National Transportation Safety Board, 2006b, p.56)**

The NTSB was able to draw many conclusions about the accident, one of which was, "The ***Lady D*** capsized as a result of the combined effects of the excessive load it carried and the wind and wave conditions experienced at the time of the accident" (National Transportation Safety Board, 2006b, p.72). The U.S. Coast Guard's position was made clear in Rear Admiral Salerno's letter that the "***Lady D***'s susceptibility to capsizing on the day of the incident was unacceptably high because the master operated the vessel in unreasonable conditions". The U.S. Coast Guard also said that the additional passenger weight diminished the likelihood of the ferry to capsize in the high winds and waves.

2.2.2 *Ethan Allen*

In Lake George Village, New York, another accident resulting in a passenger vessel capsizing and then sinking occurred in the early afternoon on October 2, 2005 (National Transportation Safety Board, 2006a). The excursion vessel ***Ethan Allen*** and its sister vessel **de Champlain** were booked by an elderly group from southwestern Michigan. The vessel had forty-eight people onboard: forty-seven passengers and the vessel master. The main cause of the accident was that the vessel was unable to sustain stability after it encountered a large wake created by another larger vessel. Other additional causes will be discussed later on in this chapter.

The group planned the round-trip tour of the southern portion of Lake George in order to see some historical sites like Fort William Henry and the Adirondack Mountains (National Transportation Safety Board, 2006a). The first sign of trouble arose when the group began to board the vessel. In Figure 2.4, the seating design on the ***Ethan Allen*** can be seen. Another photograph taken from the front of the vessel is shown in Figure 2.5. As these figures show, the left side of the vessel would clearly have more passengers than the right side thus the vessel would have a disproportional weight distribution.

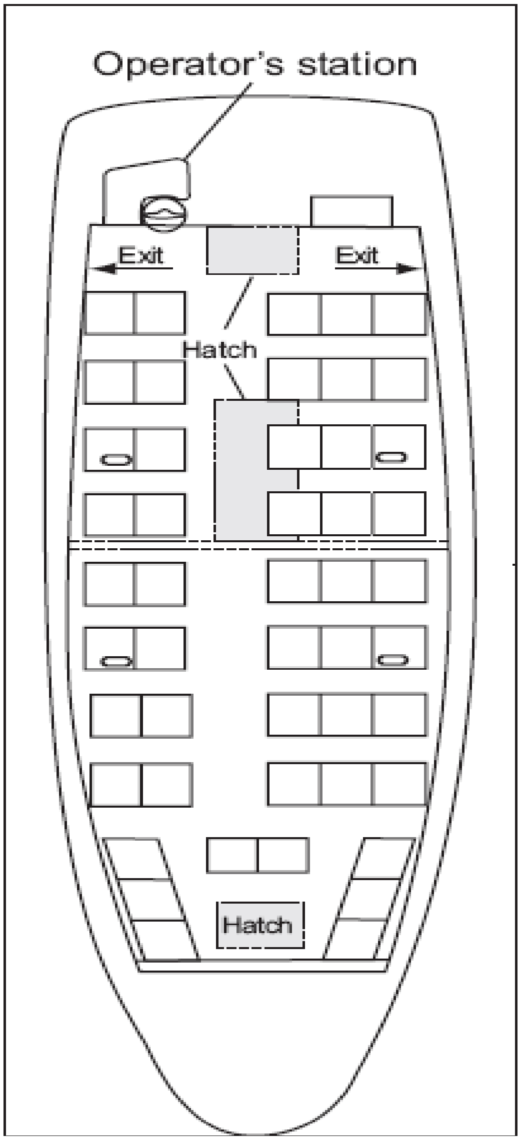


Figure 2.4: Design of the *Ethan Allen* (National Transportation Safety Board, 2006a, p.3)

Figure 2.5: Photograph taken from the Front of the *Ethan Allen* (National Transportation Safety Board, 2006a, p.3)

After about ten passengers had boarded and sat on the left side, passengers told the NTSB that they noticed the vessel began to list to the left side (National Transportation Safety Board, 2006a). One passenger commented to the rest of the group that people had to sit on the other side of the vessel as well, and the vessel master echoed this to the group. When asked about the ***Ethan Allen***’s weight distribution, another passenger told the NTSB that “we had some large people in our group … didn’t seem to be balanced” (National Transportation Safety Board, 2006a, p.3). After the NTSB conducted interviews with the surviving passengers and looked at the medical records, they estimated that the left side of the vessel had 5,088 lbs and the right side had 3,434 lbs.

Before the vessel began the trip, the captain offered seats to two more members of the group. They declined saying that they would rather go shopping instead. After the accident, these two women told the NTSB that the ***Ethan Allen*** looked “crowded” (National

Transportation Safety Board, 2006a). Another member of the group that did not board the vessel said, “I decided it wasn’t safe to be on, so I didn’t get on. I told the others that I wasn’t going” (National Transportation Safety Board, 2006a, p.3).

The weather conditions on the lake were described by passengers as “beautiful” and “perfect”, and the waters were calm (National Transportation Safety Board, 2006a). Some of the passengers that had a background in boating said that the vessel master was in control of the ***Ethan Allen*** at all times and followed the safety procedures. The accident came as a result of a larger vessel creating a wake that the vessel master did not notice until too late. In Figure 2.6, it can be seen that the accident occurred near Cramer Point about halfway through the trip.

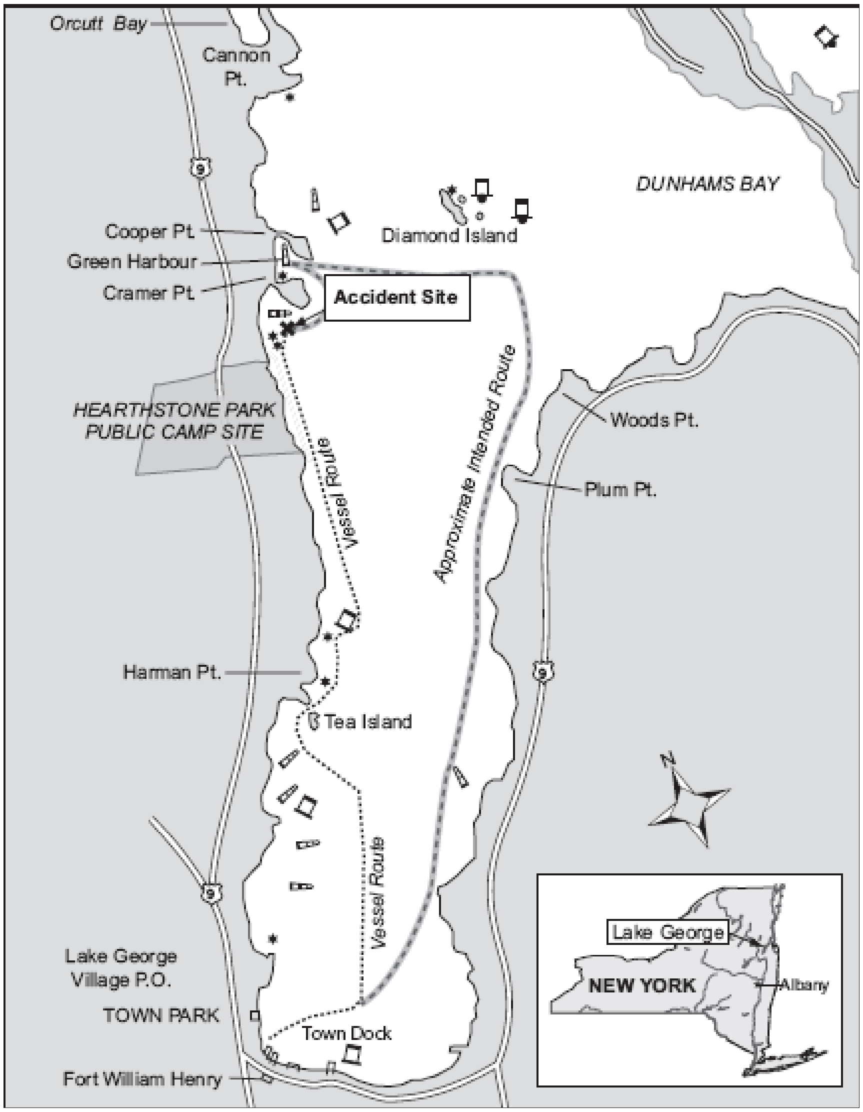
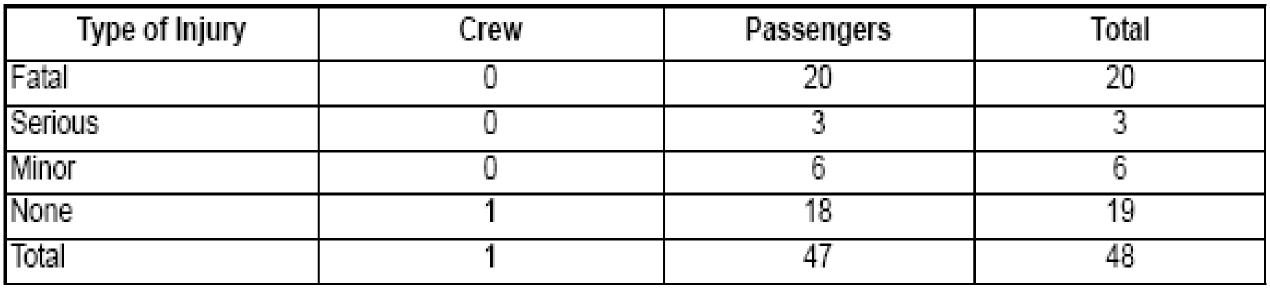


Figure 2.6: Map of Southern Part of Lake George with the Dotted Line indicating the Projected Route of the *Ethan Allen* (National Transportation Safety Board, 2006a, p.4)

There is a variety of opinions about how large the wake was that eventually caused the ***Ethan Allen*** to capsize and sink. Another boater on the lake at the time of the accident described the wake to be several inches high, but the vessel master recollected the wake as being 2 ½ to 3 feet high, which is much larger than several inches (National Transportation Safety Board, 2006a). The wake lifted the back right side of the vessel, and with the weight distribution as it was, the vessel continued to tip towards the left. Survivors recalled that passengers on the right side of the boat began to slide out of their seats towards the left side. The vessel capsized seconds after the wake struck the right side.

The ***Ethan Allen*** capsized so quickly that passengers were unable to put on lifejackets. This would seem to cause more injuries, but instead it allowed passengers to maneuver out of the overturned vessel without having to swim down into the water “against” the lifejacket (National Transportation Safety Board, 2006a). When reviewing the accident, it was determined that the vessel was equipped with fifty adult lifejackets and five child lifejackets. There were many other boaters on the lake at the time of the accident, so they were able to rescue the passengers who escaped the vessel. In Table 2.3, the distribution of the injuries incurred by people on the ***Ethan Allen*** is presented.

Table 2.3: Injuries Caused by the Capsizing of the *Ethan Allen* (National Transportation Safety Board, 2006a, p.6)



Type of Injury	Crew	Passengers	Total
Fatal	0	20	20
Serious	0	3	3
Minor	0	6	6
None	1	18	19
Total	1	47	48

The ***Ethan Allen*** was built in 1964 by Anchorage Shipyard for Whaling City Dredge & Dock Corporation, so it had to conform to the U.S. Coast Guard regulations stated in 46 CFR Subchapter T, “Small Passenger Vessels (Under 100 Gross Tons)” (National Transportation Safety Board, 2006a). This regulation stated that small passenger vessels must follow specific rules set forth. In 1979, Shoreline Cruises purchased the vessel and intended for it to be used only on New York State waters, which meant that the ***Ethan Allen*** now had to conform to the regulations of Chapter 37, “Navigation Law,” New York State Consolidated Laws. The last issued Certificate of Inspection from New York Sate was given in April 2005, six months before the accident occurred.

When the NTSB reviewed the inspections done on the vessel, they were told by the U.S. Coast Guard and Whaling City Dredge & Dock Corporation that they did not have records of a stability assessment (National Transportation Safety Board, 2006a). Shoreline Cruises did have a COI for the ***Ethan Allen*** dated May 28, 1976, that references a stability test from May 28, 1966. Because of these documents, the New York state officials did not feel that it was necessary for the ***Ethan Allen*** to undergo another stability test. A New York State regulation that was not followed was that for any vessel carrying more than twenty passengers, there must be two crew members.

Since the waters were calm, visibility was good, and temperature was 71 degrees, the NTSB concluded that the weather was not a cause of the accident (National Transportation Safety Board, 2006a). Overloading due to out-of-date passenger weight criterion and the influence of vessel motions on stability were cited by the NTSB as causes of the accident.

The ***Ethan Allen*** should have only been able to carry fourteen passengers at an average weight of 140 lbs (National Transportation Safety Board, 2006a). After conducting interviews and examining medical records, it was determined that the average passenger weight on the vessel was 178 lbs (see Appendix E for individual passenger information). This means that the ***Ethan Allen*** was carrying more than 8,500 lbs, which meant it was about 6,500 lbs overweight. The weight transfer due to passengers sliding out of their seats caused the ***Ethan Allen*** to suddenly capsize. After the accident, New York State proposed that a line be drawn on the side of each passenger vessel in order to visually see if a vessel was overweight.

The NTSB made many conclusions about the ***Ethan Allen*** accident. Two of these conclusions follow:

1. The combination of too many passengers, as permitted by the ***Ethan Allen****'s* inappropriate certificate of inspection, and the use of an out-of-date average weight standard for passengers on public vessels resulted in the ***Ethan Allen*** carrying a load that significantly reduced its stability, which made it more susceptible to capsizing on the day of the accident.
2. The ***Ethan Allen*** capsized as a result of insufficient stability, which made it unable to right itself from the combined forces of a passing wave or waves, a sharp turn, and the resulting involuntary shift of passengers to the port side of the vessel (National Transportation Safety Board, 2006a, pp.48-49).

After reviewing both of these cases, we came to the conclusion that while overloading may not have been the major cause in the accidents, it was a contributing factor in the capsizings. In the case of the ***Ethan Allen***, the vessel was carrying more than four times the weight it was capable of carrying, which is unacceptable. These accidents have highlighted the need to devise a better method to avoid overloading on passenger vessels.

2.3 Current Regulations

The United States Coast Guard currently has regulations in place designed to prevent passenger vessels from becoming overloaded. These regulations are outlined in Title 46, Subchapter S and T of the United States Code of Federal Regulations (U.S. Coast Guard, 2004). These regulations are based on the calculated stability standards for each vessel. The Coast Guard has also proposed a regulation change as a result of an increase in average passenger weight.

2.3.1 Stability Factors

Damage stability relates to the stability of a vessel while it is being flooded and under worst case loading conditions (U.S. Coast Guard, 2008 August 20). To create passenger limits, the maximum amount of weight that a vessel can hold is calculated from stability information based on the boat's type, length, height, center of gravity, and weight. From this maximum weight, the maximum amount of allowed passenger weight according to damage stability is calculated.

Intact stability relates to the stability of a vessel while it is operating under normal conditions (U.S. Coast Guard, 2008 August 20). This type of stability also accounts for non-uniform weight distribution of passengers onboard. The method for calculating the maximum number of passengers allowed on a vessel according to intact stability requirements is similar to the calculating method for damage stability requirements. A set of intact stability equations are used to evaluate the stability performance of a vessel based on the boat's type, length, height, center of gravity, and weight. From this weight, the estimated weight of the baggage, captain, and crew is subtracted. To determine the maximum number of passengers allowed onboard the vessel according to intact stability criteria, the calculated weight is then divided by an assumed weight per person of 160 pounds or 140 pounds if a mix of men, women, and children are carried on protected waters. The smaller number of passengers calculated from the damage stability requirement and the intact stability requirement is determined to be the maximum number of passengers allowed for stability requirements. However, the maximum number of passengers allowed on the vessel may still be smaller due to other safety factors.

2.3.2 Simplified Stability Test (SST)

The United States Coast Guard uses two different stability tests to determine the maximum allowable weight on each specific passenger vessel. When a vessel is built, an inclining stability test is usually done for larger vessels to accurately determine light weight and center of gravity, from which detailed loading calculations are performed. This test takes into account the damage and intact stability requirements of the vessel. When a vessel is significantly modified, its stability needs to be re-calculated. Since doing an inclining stability test is usually very expensive, the simplified stability test (SST) can be used as a substitute for smaller vessels.

Performing a SST is easier and cheaper than an inclining stability test because it can be performed at any location that allows the vessel to float in calm water. When performing the SST, a representative from the Coast Guard must be present to witness the test. The person performing the test starts by measuring and recording the dimensions of the vessel (U.S. Coast Guard, 2004 September 28). Then the total amount of test weight is loaded onto the vessel. The test weight is determined by multiplying the maximum number of people expected to be on the vessel at one time by the assumed average weight per person. The test weight is loaded so that the vessel does not heel to either side.

In the next step, the area of the side profile of the vessel is determined and multiplied by a worst case scenario wind pressure to determine the required heeling moment due to wind based on the area of vessel operation (U.S. Coast Guard, 2004 September 28). The required heeling moment due to weight is also calculated using the total test weight and the maximum beam length open to passengers. The larger of these two required heeling moments is then used as the target heeling moment for weight movement.

In the third step of the SST, an immersion mark is placed on the side of the vessel (U.S. Coast Guard, 2004 September 28). The height of this mark is determined by the distance between the waterline and the deck of the vessel under a fully loaded condition. The test weight is then moved toward the rail of the vessel while the immersion mark is monitored. If the immersion mark drops below the waterline before the target heeling moment is reached due to the position of the test weight, then the vessel fails the stability test for that number of passengers. This result means that stability test needs to be repeated with a reduced total weight.

2.3.3 Effectiveness of Current Regulations

Events in the United States show that the current regulations being used to determine the amount of weight onboard passenger vessels are not accurate. The calculations used to determine the maximum number of passengers allowed onboard a vessel uses an outdated average passenger weight. In the ***Lady D*** passenger pontoon accident, the vessel was carrying a total amount of weight about 700 pounds greater than what it should have been (National Transportation Safety Board, 2006b). The boat was able to carry 3500 pounds. of passenger weight, but the average weight per person on the vessel was 168 pounds. This meant that the boat should have only been carrying twenty passengers, or 3360 pounds. This shows that the current weight regulations do not provide the vessel master with adequate information regarding the amount of weight on the boat.

2.3.4 United States Coast Guard Proposed Rule Change

In order to combat the problem of passenger vessel overloading, the U.S. Coast Guard is proposing a rule change to their current regulations regarding loading on passenger vessels. When calculating the number of passengers that are allowed to travel on a vessel, one factor that the U.S. Coast Guard takes into account is the average weight of a passenger (U.S. Coast Guard, 2008 August 20). For vessels that operate in strictly protected waters and carry men, women, and children, the assumed passenger weight used is 140 pounds. For all other vessels, the assumed passenger weight used is 160 pounds. The proposed regulation change states that for all instances of weight calculations an average weight of 185 pounds. should be used to more accurately reflect the weight of the average American. Even though this proposed rule is not yet in effect, the Coast Guard is recommending that all passenger vessels use the new assumed weight per passenger of 185 pounds.

The Coast Guard's proposed rule also states that every ten years passenger vessels would be required to verify their stability (U.S. Coast Guard, 2008 August 20). This would need to be done by means of a SST. This reoccurring stability testing will ensure that vessel stability letters stay up-to-date, and the weight of any added load and small modifications on the vessel are taken into account with the vessel's stability.

2.4 U.S. Demographic Changes

Over time, countries have seen many demographic and biophysical changes in their citizens. These changes have been seen on a national level, but centralized in different regions of a country. One noticeable change that has occurred is the increase in average weight of a person. In 2002, the average weight for an American citizen had increased by approximately 24.4 pounds since 1960. Studies conducted by the Centers for Disease Control and Prevention, National Center for Health Statistics (Ogden, 2004) had shown that the average weight of the average American man and woman had increased by about eight pounds per decade since 1960. In 2006, the average weight had increased by approximately 26.5 pounds since 1960, conveying the message that not only are Americans gaining weight, but that they are gaining weight quickly (McDowell, 2008). Table 2.4 shows the average weights of American males and females in regard to a specific four-year time period. We were able to conclude that the increase in weight can lead to an increase in risk for passenger vessels if the correct average weight is not used.

Table 2.4: U.S. Average Weights (Center for Disease Control, 2004, p.8; Center for Disease Control, 2008, pp.7-10)

Gender and Age	**Weight 1960-1962**	**Weight 1999-2002**	**Weight 2003-2006**
Males ages 20-74	166.3	191.0	194.7
Females ages 20-74	140.2	164.3	164.7

2.5 Legal Issues

When interacting with society, it is always necessary to keep in mind people's civil rights. For our project, it is necessary to consider a person's right to privacy versus the government’s necessity to promote public safety. Two federal statutes were found that discussed a person’s right to privacy, The Privacy Act of 1974 and The Freedom of Information Act.

Dr. Kent Rissmiller, an associate professor at WPI, offered to help assist us in better understanding this topic. Dr. Rissmiller explained the government’s position on the issue of privacy versus public safety. He explained what the government categorized as private (bank account numbers, social security numbers) and what is categorized as personal (anything that has the potential to be public knowledge, but is not willingly released to the public). In his opinion, the process of weight measurement deals with gaining personal information rather than private information. Dr. Rissmiller continued to explain that in reality there are no laws that protect the personal information of U.S. citizens. He explained that using certain methods to try to retrieve personal information would not be illegal, but it might not be accepted by the public and could therefore stall the implementation of such a method (example: weighing people on scale, one at a time before boarding a vessel). Dr. Rissmiller clarified that the government has established that anything in a public space is considered public information.

2.6 Research into Possible Solutions

To determine possible solutions for preventing vessels from becoming overloaded, we researched different methods of measuring, monitoring, and estimating weight. The Federal Aviation Administration has two methods for monitoring the weight onboard airplanes. There are also various scientific methods for determining the weight of an object or objects. In addition to these methods, we looked at the possibility of using load marks, a method currently used for monitoring the weight on large vessels.

2.6.1 FAA Weight Regulations for Airplanes

The Federal Aviation Administration (FAA) has weight regulations in place that the airline industry must adhere to prior to departure. The regulations are specifically devised for the three different aircraft cabin sizes: large, medium, and small. The large cabin aircrafts, which carry more than seventy passengers, use the standard average weight method (Federal Aviation Administration, 2005, p.17). This method denotes a summer weight with no carry-on for men, women, and children between the ages of two and thirteen years old that is 194 lbs., 173 lbs., and 76 lbs. respectively (p.20).

The small cabin aircrafts, which carry between five and twenty-nine passengers, use a different method with segmented weights for adult passengers (Federal Aviation Administration, 2005, p.28). This method accounts for the ratio of males to females. The medium cabin aircrafts, which carry between thirty and seventy passengers, are designated as either being closer to a large cabin aircraft and would use the standard average weight method or closer to a small cabin aircraft and would use the segmented average weight method.

The FAA also has stipulations that must be followed depending on the type of airplane flight. These stipulations account for the time of year and for a passenger that has carry-on luggage (Federal Aviation Administration, 2005, p.17). The FAA split the year into two parts: summer (May 1st – October 31st) and winter (November 1st – April 30th) months. The time of year is important because a passenger has more clothing in winter months than in summer months. Both of the methods described above are based on the summer months and to account for the extra clothing during winter months, the FAA encourages adding five pounds to the weight of each passenger.

The other stipulation regarding carry-on luggage needs to be accounted for by the airplane before it departs because it can have a large effect on the amount of weight being carried. The FAA has determined that the average passenger has about sixteen pounds of personal items and carry-on luggage (Federal Aviation Administration, 2005, p.17). If an airplane allows carry-on luggage, the airplane should then add six pounds to the average passenger's weight (p.20).

2.6.2 Methods for Measuring Weight

There are three primary methods used in commercially available scales for measuring the weight of an object. These methods are weight comparison, springs, and strain gauges. Scales utilizing one of these different methods can be used for measuring the weight of passengers boarding a passenger vessel.

Scales that use a weight comparison are used to accurately measure the mass of an object. These scales are commonly called balances and they compare the mass of a known quantity to that of an unknown quantity to determine the mass of the unknown quantity. These balances usually use a lever system to compare the two masses. Since balances operate independent of the value of the gravitational force, they can accurately determine the mass of an object unlike other scales that are dependent on the value of the gravitational force. If a balance is used to measure the mass of passengers, then the passengers' weight can be calculated by taking into account the value of acceleration due to gravity at the location where the passengers are being measured.

Spring scales are another method that can be used to accurately determine the weight of passengers boarding a passenger vessel. A spring scale has a platform that is oriented perpendicular to the force of gravity. The spring is located perpendicular to the platform (Brain, 2008). The side of the spring not supporting the platform needs to be attached to an immovable surface. When an object is placed on the platform, the spring will stretch or compress from the weight of the object and when the spring displacement is measured, the weight of the object can be determined.

Scales utilizing strain gauges are also common among commercially available scales. Strain gauges are usually found within a load cell (Choosing Load Cells for Industrial Weighing, 2008). A scale can have one or several load cells below the main platform. The platform of the scale is oriented perpendicular to the force of gravity and the load cell is between the gravitational source and the load cells are oriented parallel to the force of gravity. Load cells typically contain a piece of metal that bends or becomes deformed when a force is applied to it. Strain gauges are attached to this piece of metal and the strain gauges can measure the amount of deflection or deformation caused in the piece of metal. This in turn is used to calculate the weight of the object on the platform of the scale.

2.6.3 Load Lines

One method that the U.S. Coast Guard uses to prevent overloading on larger vessels (>65 feet in length) is by having load lines on the sides of the vessels that meet certain requirements. Vessels that operate on the Great Lakes or on the high seas are required to have load lines if they meet either of these two requirements: 1) all vessels of seventy-nine feet or over in length, or 2) all vessels of 150 gross tons or over (Office of Federal Register National Archives and Records Administration, 2004, p.14). When determining where the load lines should be placed, both structural efficiency and satisfactory stability are taken into account.

The load line is placed at the amidships on both sides of the vessel. It is painted in either white or black depending on the color of the vessel's hull (Office of Federal Register National Archives and Records Administration, 2004, p.31). There are several different load lines that refer to the type of water and the season that the vessel is traveling in. A photograph of load lines can be found in Appendix J.

Each vessel is required to have a load line certificate which is valid for five years (Office of Federal Register National Archives and Records Administration, 2004, p.17). There are four types of certificates issued: International, Special Service, Domestic Service and Great Lakes. The U.S. Coast Guard has the authority to penalize vessels for violating any of the rules set forth in 46 Subchapter E- Load Lines. These penalties include, but are not limited to, the following: detain the vessel if deemed overloaded, assess and collect applicable monetary penalties, initiate a criminal prosecution, or suspend the master and/or owner from operating (Office of Federal Register National Archives and Records Administration, 2004, p.18).

There are many factors that affect the way standards and regulations are established. Things such as previous case studies, demographical changes, and legal issues all affect these guidelines. As previous case studies have shown, it is necessary to constantly evaluate standards and regulations for passenger vessels in order to keep people safe. To monitor the weight onboard passenger vessels, it may be necessary to develop a new method besides counting passengers. FAA methods, weight measuring methods, and load lines are methods that could be applied to vessel loading in order to monitor it more closely.

3.0 Methodology

In order to understand and determine possible solutions for the problem of passenger vessel overloading, we used several different research methods. We also determined the factors when overloading is most likely to occur. Our methods and the criteria for determining the best solution are explained in this chapter.

3.1 Factors of Vessel Overloading

There are many different types of passenger vessels and different situations where overloading is most likely to occur. Because of this, we determined what these situations were and designed our proposed solutions to be most effective in these situations. To obtain this objective, we took into account the hours of the week in which vessel companies are operating with a high volume of passengers, the amount of profit made by the vessel company for each passenger, and the stability of the vessel.

3.1.1 Peak Hours

In order to determine specific situations where more accurate calculations are required, we needed to determine which hours of the day are peak hours for different passenger vessel companies. We met with U.S. Coast Guard economist Mr. Reed Garfield and defined peak hours as the hours when the passenger vessels are making trips at ninety percent capacity or greater (October 30, 2008). We determined these hours because if a vessel is traveling with less than ninety percent capacity, then we believe that the vessel will not be overweight.

Based on the advice of Mr. Garfield, we asked vessel masters and managers a variety of questions regarding the passenger vessel industry (October 30, 2008). Interviews with these masters and managers can be found in Appendix G. Each manager told us if and how they recorded the number of passengers on their vessels before leaving port at all times. If a manager did not keep records, we asked how often and during which hours their passenger vessels are at about ninety percent capacity or greater. Knowing a passenger vessel's peak hours would alert the master when stricter solutions would need to be used.

3.1.2 Profit per Voyage

Identifying the amount of money that each passenger spends per voyage provides a passenger vessel company with information that would help them choose one of our proposed solutions. We were advised by Mr. Garfield that we should notify vessel companies to record all types of revenue generated while on a voyage (October 30, 2008). This revenue includes any concessions, souvenirs, etc., sold while the passenger vessel is en route.

This could affect a vessel company's decision in different ways. A passenger vessel that generates most of its profit from ticket sales may prefer a very precise solution even if was expensive. A vessel would incur the price to implement a solution so that the vessel could maintain a high passenger count. On the other hand, a vessel company that generates most of its profit from concessions, souvenirs, etc. would prefer an accurate solution that was inexpensive. A vessel would favor an inexpensive solution because the amount of tickets sold is not the majority of the revenue.

3.1.3 Stability Problems

In order to determine when our solution should be applied or to which vessels it needs to be applied, we looked at the stability of different vessels, how this stability is calculated, and how the number of passengers and their weight affect the vessel's stability. Mr. William Peters, a United States Coast Guard Naval Architect informed us that the *Code of Federal Regulations* would provide us with a better understanding of how vessel stability is regulated for different types and the different types of stability tests that are used to check vessel stability.

3.2 Determining Possible Solutions

In order to arrive at our proposed solutions, we analyzed several possible solutions. These possible solutions were determined by looking at information from the National Center for Health Statistics and the Federal Aviation Administration, talking to U.S. Coast Guard experts, and formulating our own ideas. How we determined our possible solutions is explained in this section.

As mentioned in Chapter 2, the Simplified Stability Test (SST) is one type of the stability tests used by the Coast Guard. We researched the SST to gain a better understanding of what the test entails. We then continued our research by looking at completed SST forms to directly see how the stability of different vessels was influenced by the number of people onboard. This information was then analyzed to give us an idea of when our solution could encounter overloading and to which vessels they should apply.

3.2.1 National Center for Health Statistics

The Coast Guard has been using an outdated passenger weight for the average American adult. This outdated passenger weight is the root cause of passenger vessel overloading. To fix this problem, we needed to establish the correct current weight for the average American adult. We did this by looking at studies published by the Centers for Disease Control (CDC).

When we first started this process, we found a report on Body Mass Index published by the National Center for Health Statistics, a division of the CDC (2004). The report contained a study on how the average weight of Americans had increased from 1960 to 2002. Although this information was very enlightening, we thought that it was necessary to find information that was more up to date.

Further research lead us to find a second report published by the National Center for Health Statistics (2008) on anthropometric measurements for children and adults in the United States from 2003 to 2006. This was the most recently published and updated information that we analyzed in order to determine the average weight to use in our recommendation. The data we used from this report can be seen in Appendix F.

3.2.2 Determining Weight on Airplanes

Another approach that we used to find more solutions to combat the problem of overloaded passenger vessels was to examine the methods used by airlines to ensure their planes are not overweight before takeoff. The system that airlines use is relevant because it has to be very accurate and reliable. Crashes, which would cause serious injuries to passengers and people on the ground, could occur when an airplane is unable to operate correctly because it is carrying more weight than allowed.

We specifically chose the airplane industry because they have to take into account the passenger’s carry-on luggage and traveling season. Traveling by plane during summer versus winter months entails having to compensate for additional weight caused by passengers wearing winter clothing. The airline’s method relates to water-based passenger vessels because people use them as a means of transportation and for recreational activities throughout the year. Some of the vessels considered in our study also allow passengers to bring suitcases and other carry-on luggage onboard. The additional weight plays an important role in determining whether a passenger vessel is overweight.

3.2.3 Passenger Vessel Experts

To accomplish our goal of being able to assure vessel masters that they have not surpassed their maximum allowable weight, it is necessary that we recommend effective techniques that would achieve this goal. To find possible solutions, we also spoke with different experts in the passenger vessels industry to see if their experience and insight could offer any possible solutions and also give us their opinions on the solutions that we had already established.

We spoke with Mr. Peters, who is very knowledgeable on the subject of passenger vessel overloading. He presented new ideas that we had not thought of before. We also asked him about the feasibility of other potential solutions. We took Mr. Peters’ advice into account when analyzing our solutions and making our final recommendation.

We also spoke with Mr. Marc Cruder, a traveling marine inspector for the United States Coast Guard, and Mr. Peter Lauridsen, the regulatory affairs consultant for the Passenger Vessel Association. The purpose of our meeting with them was to discuss the solutions we were analyzing and get their viewpoint on how applicable the solutions would be to the passenger vessel industry. Our discussion was extremely helpful, but reinforced the need to potentially have different solutions for different types of vessels or for vessels with different purposes.

3.3 Criteria for Determining the Best Recommendation

By completing our research, we were able to develop possible solutions to solve the problem of passenger vessel overloading. As we identified possible solutions, we evaluated them to determine which one was the best solution. We decided that the criteria important for evaluating each possible solution were efficiency, ease of implementation, enforceability, and accuracy.

3.3.1 Efficiency

We evaluated each possible solution to determine how efficient it was. We defined efficiency by the amount of time that it would take to determine if the passenger vessel is overloaded. We also spoke with passenger vessel companies to determine the arrival and departure times and the amount of time for weight calculations available before a passenger vessel leaves port. This was to ensure that our possible solution would not alter the day-to-day procedures of the passenger vessel company in a way that would cause the business to lose money. From talking with vessel companies we also determined the different methods that they use for distributing tickets. We then evaluated each possible solution and determined if the amount of time it required was acceptable.

3.3.2 Ease of Implementation

Implementing some of our proposed solutions may take time and money on the part of the U.S. Coast Guard and the individual passenger vessel companies. We used semi-structured interviews with U.S. Coast Guard Marine Architects and Engineers to determine what the acceptable time and cost for implementation is for different types of vessel companies. We also recognized that some possible solutions may be too difficult to implement because the resources necessary are not easily available. Using this information we evaluated each possible solution and determined what factors were involved with implementing each solution and if these factors were acceptable.

3.3.3 Enforceability

Our proposed solution needed to be easily enforceable by the vessel companies who might be utilizing them. Therefore, we evaluated each of our possible solutions to determine how easily each would be to enforce. We defined enforceability as the ability of a vessel company to prevent overloading during its ticket selling process. This criterion was made to evaluate the human factor involved in possibly needing to ask passenger to exit a vessel when it is overweight. If a solution determines the amount of weight for a specific voyage at the time when tickets are sold then it is easier to enforce because loading can be controlled by stopping the sale of tickets. If it is determined at the time of boarding then it is a solution that is more difficult to enforce. If a possible solution was not easy to enforce it was not discarded since we believe it still may be a practical solution.

3.3.4 Accuracy

In order for our solution to be worth implementing it needed to be accurate. The main problem with the current method for determining the weight being loaded onto a passenger vessel is that it is not always accurate. Our proposed solutions did not need to be exact, but they needed to be able to accurately determine whether or not a passenger vessel is overloaded. To evaluate our possible solutions for accuracy, we created a computer program that would simulate different loading scenarios. The program utilizes the database of the Centers for Disease Control's raw biometric data on American citizens to randomly select a passenger sample based on the parameters that are set before the simulation is run. A diagram of the software program we created can be seen in Appendix L.

Using this program, we were able to see how often each possible solution conservatively estimated the actual total weight on a vessel. We were also able to determine each solution's total difference and standard deviation. We defined total difference as the difference for specific loading scenarios between the average total weight that a solution calculated and the actual average total weight. We were also able to look at which solutions worked best in extreme loading scenarios from using our simulations.

In order to determine the best solution to the problem of passenger vessel overloading, we determined the situations where overloading is most likely to occur and we looked at how passenger vessel stability is calculated. In order to get ideas for possible solutions, we looked at how the FAA does weight calculations for airplanes in the United States and we talked with U.S. Coast Guard experts and asked for their ideas on possible solutions. The following chapter provides the results we obtained when we evaluated the possible solutions based on the criteria of efficiency, ease of implementation, enforceability, and accuracy. The solution that best met these criteria then became our proposed solution.

4.0 Results and Analysis

In this chapter we will present twelve possible solutions that the U.S. Coast Guard could adopt as regulations to help passenger vessels avoid overloading. These solutions include weight estimation methods, average weight methods, and using physical methods to determine the total amount of weight on a vessel. The solutions were analyzed based on the following criteria: efficiency, ease of implementation, enforceability, and accuracy. Our analysis of these options allowed us to make a well-informed recommendation to the Coast Guard.

4.1 Possible Solutions

The possible solutions that we identified would allow vessel masters to determine if their vessel is overweight. They are divided into three categories: weight estimation methods, average weight methods, and physical methods. All of our possible solutions are described in this section.

4.1.1 Weight Estimation Methods

This section contains descriptions of solutions that primarily deal with weight estimation methods. The four solutions include Asking Passengers their Weight, Number Approximations, Estimations by Size, and Load Marks.

Asking Passengers Their Weight

One of our first responses to the problem of passenger weight overloading was the thought of simply asking passengers their weight. We established that this could be applied when passengers were buying tickets online or at the ticket booth. When applied to online ticket buying, the computer program used to sell tickets could be adjusted to calculate the total passenger weight. When applied at a ticket booth, the ticket seller would ask each passenger his or her weight and continually add the weight with a calculator. Implementing this method would require one or two people at a ticket booth and no additional staff if the information was submitted online. At a ticket booth, if more than one sales person were selling tickets for the same vessel, it would be necessary to have the sellers asking each passenger his or her weight, and a third person calculating the total weight using the following equation:

$$(P_1 + P_2 + P_3 + P_4 + \ldots + P_{n-1} + P_n) \leq M$$

Where:

P= Passenger's Weight

n= Total Number of Passengers

M= Maximum Allowable Weight on the Vessel

By asking all of the passengers boarding a vessel how much they weigh, a passenger vessel company could determine how much passenger weight is on the vessel. One potential problem with this solution is that passengers may not want to tell employees of a vessel company how much they weigh. To avoid embarrassment, some passengers may also lie about their weight.

Number Approximations

Another solution that could be used to prevent passenger vessels from becoming overloaded is by using number approximations. Table 4.1 describes the specific number that would be assigned to men, women, children and large luggage. The idea behind this solution is that the average weights of men, women, and children as defined by the Centers for Disease Control, are very close to multiples of 33.3 pounds. By rounding to the nearest multiple, the multiples of 33.3 pounds can then be reduced to a much more manageable number for doing arithmetic.

Table 4.1: Number Approximations for Average Weights (Center for Disease Control, 2008, pp.7-10)

	Avg. Weight (lbs.)	Rounded (lbs.)	Approximation Number
Men	194.7	200	6
Women	164.7	167	5
Children	93.8	100	3
Large Luggage	33.3	33	1

The average weights presented in Table 4.1 are based on data released by the Centers for Disease Control in 2008. These weights were determined by considering a child to be between the ages of one and seventeen years old and an adult to be older than seventeen years old. An approximation number of one corresponds to a weight of 33.3 pounds so each approximation number is determined by the following equation:

$$N_{Approx\,\#} = W_{Average} / 33.3$$

Where:

$N_{Approx\,\#}$ = *Approximation Number*

$W_{Average}$ = *Average Weight Rounded*

To use this solution, one employee would be required to record the appropriate approximation number for each passenger. As passengers purchase tickets or board the vessel, the employee would add up the approximation numbers and compare the sum to the maximum number that is allowed on the vessel. An approximation number of one can also be added to the total if the passenger is carrying a large piece of luggage that might weigh close to 33.3 pounds. In order to determine the maximum approximation number for the vessel, the following equation can be used:

$$M_{Number} = M / 33.3$$

Where:

M_{Number} = *Maximum Approximation Number*

M = *Maximum Allowable Weight on the Vessel*

When the running sum is equal to the maximum number allowed on the vessel, no more passengers would be allowed on the vessel.

Estimations by Size

An approximate weight for each passenger can be estimated based on a person's height and waist size. These weights are outlined in Table 4.2. The average weight values in the table are determined from the data released by the CDC on average body weights, heights, and waist sizes in the United States. The table is based on the assumption that a short person with a small waist weighs less than a tall person with a large waist. For this solution to work, an employee must be trained to accurately judge each passenger that boards the vessel.

Table 4.2 Estimations by Size (Center for Disease Control, 2008, pp.7-10)

		Height		
		Short	Middle	Tall
Waist	Small	157	168	180
	Average	168	180	194
	Large	180	194	209

In Tables 4.3 and 4.4, the actual heights and waist sizes that should be used are outlined. These height and waist values are based on the CDC's data using the 25th, 50th, and 75th percentile for average values. These percentiles make up the small, medium, and large values, respectively. Using these values, the average weights of adults in the United States in the 25th, 50th, and 75th percentile were matched to the nine categories. Using this solution, the 25th percentile weight is equal to a small and short person, the 50th percentile weight is equal to an average and middle person, and the 75th percentile weight is equal to a large and tall person. From those values, the average weights for other six categories are filled in.

Table 4.3: Average Heights based on CDC Data (Center for Disease Control, 2008, pp.11-16)

	Height (in.)
Short	64.5
Average	66.6
Tall	68.9

Table 4.4: Average Waist Sizes based on CDC Data (Center for Disease Control, 2008, pp.21-23)

	Waist (in.)
Small	33.9
Average	37.7
Large	42.1

Table 4.2 would be held by an employee who monitors passengers boarding a vessel. The employee would then have to judge each passenger to determine which category they would fall into. While passengers are boarding, the employee would need to keep a running sum of the weight on the vessel and prevent people from boarding once the vessel has reached its maximum allowable weight. Performing this solution would require the employee to use a calculator to keep track of the total amount of weight on the vessel. One potential problem

that could arise from this situation is human error. If the employee doing the judging is not good at determining which category each passenger fits into then this solution will not work.

Load Marks

A possible solution that we investigated was the use of load marks on all passenger vessels. Load marks were considered because they would not involve subjecting passengers to any weighing estimates or techniques. The Coast Guard currently uses load lines on vessels that meet a certain criteria (See Section 2.6.3). They have also established criteria for how these load lines are applied to the vessels and how they are read (See Appendix J). A load mark differs from load lines because a load mark would mean only one mark on the vessel, whereas load lines refer to multiple marks on the vessel.

The concept behind using load marks is simple. A load mark of a certain dimension would be painted on the hull of the vessel, a certain distance from the top of the deck. An employee would monitor the position of the load mark in relation to the water level. As passengers or cargos are loaded onto the vessel, the vessel will sit lower in the water, and the load mark will start to submerge. The crew can continue to load the vessel until the top of the load mark is at the water line. If the top of the load mark is completely submerged under water then the vessel is overloaded and some weight must be removed from the vessel.

4.1.2 Average Weight Methods

The descriptions in this section are of solutions that use average weight data collected from different government agencies. The solutions include USCG Proposed Weight, Centers for Disease Control (CDC) Weights, FAA Standard Weights, and FAA Segmented Weights.

USCG Proposed Weight

We reviewed the U.S. Coast Guard’s Proposed Rule Change and decided that this would be evaluated under the same criteria as each of our other possible solutions. The new average weight that the U.S. Coast Guard wants to establish is 185 pounds (U.S. Coast Guard, 2008 August 20, p.49246). The stability tests would have to be adjusted to incorporate the higher average weight. The new equation that would result from this weight adjustment is:

$$M / 185 \text{ lbs} = N_{Maximum}$$

Where:

$N_{Maximum}$ = *Maximum Number of Passengers Allowed*

M =*Maximum Allowable Weight on the Vessel.*

Centers for Disease Control (CDC) Weights

Another simple solution that we identified to estimate weight is using the most recent National Health Statistics Report to determine the average weights of American adult males and females. These weights are 195 pounds and 165 pounds for adult males and females, respectively (McDowell, 2008, pp.8-10). We did not include people under the age of twenty years old in this average weight because of the disparity of sample sizes between the age groups. Our solution requires an employee to count the number of males and females as they board the vessel. The equation that vessel companies would have to adhere to is as follows:

$$(N_{Males} \times 195lbs) + (N_{Females} \times 165lbs) \leq M$$

Where:

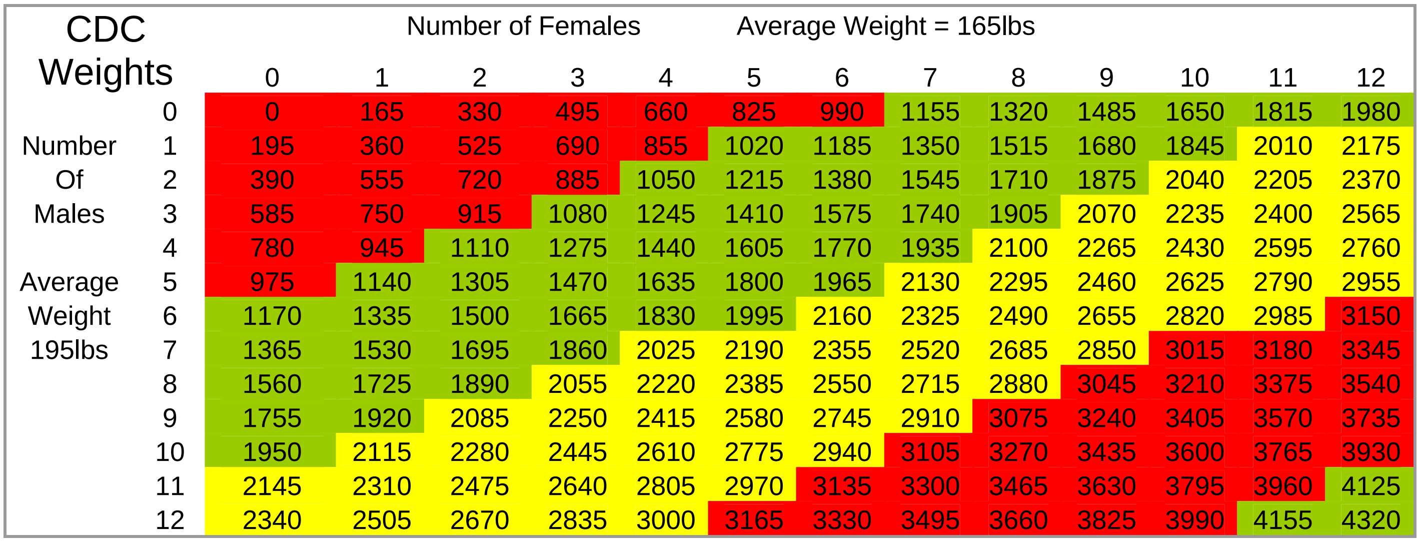
N_{Males} = *Total Number of Males*

$N_{Females}$ = *Total Number of Females*

M = *Maximum Allowable Weight on the Vessel*

Table 4.5 contains a table that has the computed weight for the varying number of males and females.

Table 4.5: CDC Weights Table

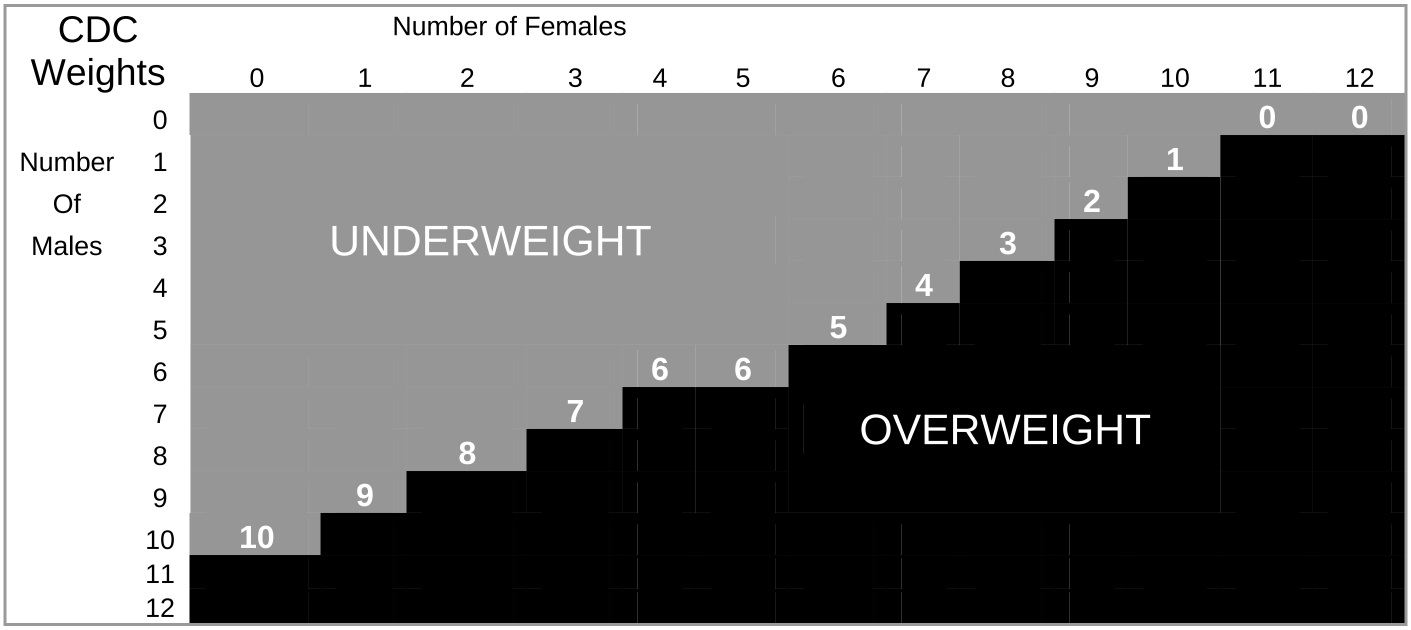


CDC Weights		Number of Females				Average Weight = 165lbs								
		0	1	2	3	4	5	6	7	8	9	10	11	12
	0	0	165	330	495	660	825	990	1155	1320	1485	1650	1815	1980
Number	1	195	360	525	690	855	1020	1185	1350	1515	1680	1845	2010	2175
Of	2	390	555	720	885	1050	1215	1380	1545	1710	1875	2040	2205	2370
Males	3	585	750	915	1080	1245	1410	1575	1740	1905	2070	2235	2400	2565
	4	780	945	1110	1275	1440	1605	1770	1935	2100	2265	2430	2595	2760
Average	5	975	1140	1305	1470	1635	1800	1965	2130	2295	2460	2625	2790	2955
Weight	6	1170	1335	1500	1665	1830	1995	2160	2325	2490	2655	2820	2985	3150
195lbs	7	1365	1530	1695	1860	2025	2190	2355	2520	2685	2850	3015	3180	3345
	8	1560	1725	1890	2055	2220	2385	2550	2715	2880	3045	3210	3375	3540
	9	1755	1920	2085	2250	2415	2580	2745	2910	3075	3240	3405	3570	3735
	10	1950	2115	2280	2445	2610	2775	2940	3105	3270	3435	3600	3765	3930
	11	2145	2310	2475	2640	2805	2970	3135	3300	3465	3630	3795	3960	4125
	12	2340	2505	2670	2835	3000	3165	3330	3495	3660	3825	3990	4155	4320

A change of background color represents a change of 1,000 pounds. Table 4.6 is an application of how the CDC Weights Table would be used for a vessel in summer months with a no carry-on luggage policy. Table 4.6 corresponds to a vessel that can carry a maximum weight of 2,000 pounds. If the number of male and female passengers is in the gray area, the vessel is considered to be carrying less than 2,000 pounds. On the contrary, if the number of male and female passengers is in the black area, the vessel is considered to be carrying more than 2,000 pounds.

In Table 4.6, the white text refers to the maximum number of males allowed given the number of females in the corresponding column. For example, if seven females board this vessel, four males would be the maximum that could accompany them.

Table 4.6: Application of the CDC Weights Table



CDC Weights		Number of Females												
		0	1	2	3	4	5	6	7	8	9	10	11	12
	0												0	0
Number	1											1		
Of	2										2			
Males	3			UNDERWEIGHT						3				
	4								4					
	5							5						
	6					6	6							
	7				7					OVERWEIGHT				
	8			8										
	9		9											
	10	10												
	11													
	12													

FAA Standard Weights

One of the solutions that the Flight Aviation Administration (FAA) currently uses involves assigning an average weight of 194 pounds, 173 pounds, and 76 pounds to men, women, and children, respectively (Federal Aviation Administration, 2005, p.20). If the vessel is operating during winter months, November 1st – April 30th, five pounds would be added to the previously mentioned weights to account for the additional clothing. Thus the equation for this solution is as follows:

$$
\begin{aligned}
&(N_{Men} \times [194lbs\ (+5lbs\ in\ winter\ months)]) \\
&+ (N_{Women} \times [173lbs\ (+5lbs\ in\ winter\ months)]) \\
&+ (N_{Children} \times [76lbs\ (+5lbs\ in\ winter\ months)]) \\
&\leq M
\end{aligned}
$$

Where:

N_{Men} = *Number of Men (14 yrs old +)*

N_{Women} = *Number of Women (14 yrs old +)*

$N_{Children}$ = *Number of Children (2-13 yrs old)*

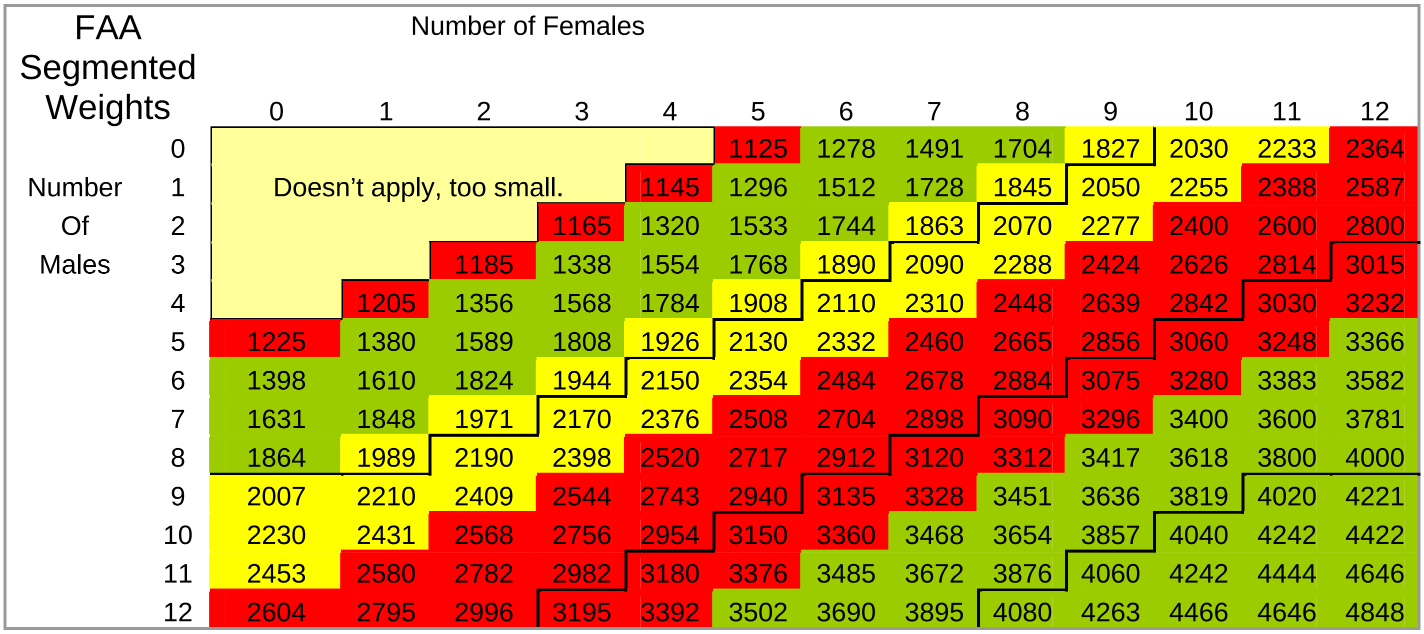
M = *Maximum Allowable Weight on the Vessel.*

FAA Segmented Weights

The other solution that the FAA uses is a segmented average passenger weight. This solution adjusts the average weight of a passenger depending on the number of passengers and the ratio of males to females (Federal Aviation Administration, 2005, p17). The FAA determined that an average male weighs approximately twenty pounds more than an average female. Appendix K contains two tables. The first table distinguishes the average weights that are associated with a specific number of passengers and a certain ratio of males to females. The second table computes the weight based on the average weight found in the first table.

Table 4.7 is the FAA Segmented Weights Table. A change of background color now corresponds to a change in the class of total passengers being used. The bold lines represent the change of 1,000 pounds. In order to compare this solution with the CDC Weights solution, Table 4.8 is an application of how the FAA Segmented Weights Table would be used in summer months with a no carry-on luggage policy. Table 4.8 corresponds to a vessel with a maximum weight of 2,000 pounds. Again, the gray area is considered to be less than 2,000 pounds, while the black area is considered to be more than 2,000 pounds.

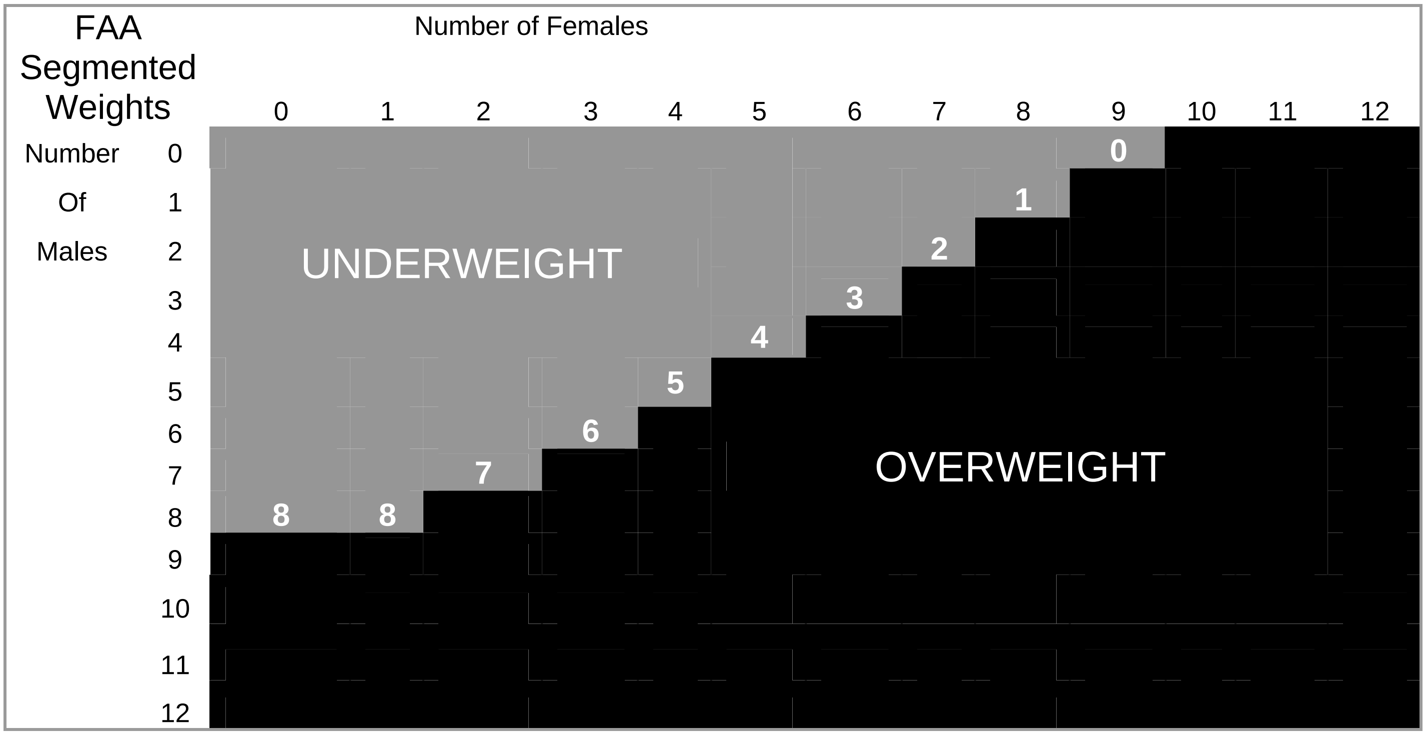
Table 4.7: FAA Segmented Weights Table



FAA Segmented Weights		Number of Females												
		0	1	2	3	4	5	6	7	8	9	10	11	12
	0	Doesn't apply, too small.					1125	1278	1491	1704	1827	2030	2233	2364
Number Of Males	1					1145	1296	1512	1728	1845	2050	2255	2388	2587
	2				1165	1320	1533	1744	1863	2070	2277	2400	2600	2800
	3			1185	1338	1554	1768	1890	2090	2288	2424	2626	2814	3015
	4		1205	1356	1568	1784	1908	2110	2310	2448	2639	2842	3030	3232
	5	1225	1380	1589	1808	1926	2130	2332	2460	2665	2856	3060	3248	3366
	6	1398	1610	1824	1944	2150	2354	2484	2678	2884	3075	3280	3383	3582
	7	1631	1848	1971	2170	2376	2508	2704	2898	3090	3296	3400	3600	3781
	8	1864	1989	2190	2398	2520	2717	2912	3120	3312	3417	3618	3800	4000
	9	2007	2210	2409	2544	2743	2940	3135	3328	3451	3636	3819	4020	4221
	10	2230	2431	2568	2756	2954	3150	3360	3468	3654	3857	4040	4242	4422
	11	2453	2580	2782	2982	3180	3376	3485	3672	3876	4060	4242	4444	4646
	12	2604	2795	2996	3195	3392	3502	3690	3895	4080	4263	4466	4646	4848

In Table 4.8, the white text in the table refers to the maximum number of males allowed given the number of females in the corresponding column. For example, if seven females board this vessel, two males would be the maximum that could accompany them. In comparison with the CDC Weights, this solution allows fewer passengers.

Table 4.8: Application of FAA Segmented Weights Table



4.1.3 Physical Methods

This section includes the descriptions of our solutions that involve a physical device that would be used to determine the weight of passengers boarding the vessel. These solutions include Scales, Fulcrum, Floating Barge, and Five Gates.

Scales

Another possible solution for determining whether a passenger vessel is overloaded is weighing the passengers that are boarding the vessel on a scale. This can be done by weighing people individually or in a group as they board a vessel. Appendix I outlines examples of scales that could possibly be used.

If this solution were to be used, there would need to be at least one employee available. This employee would be required to instruct the passengers to step onto and off of the scale as well as keep track of the weight of the passengers getting onto the vessel. When the weight of the passengers boarding the vessel is equal to the maximum allowable weight on the vessel, the employee will stop allowing passengers to board the vessel.

Fulcrum

When looking into methods to solve the problem of weight overloading on passenger vessels, we came up with many solutions, but we also were given a few suggestions. One suggestion given to us by Mr. Peters was to use a fulcrum to measure the weight of people boarding a vessel. It would be built so that there would be a lever with a platform on one side and a specific amount of weight on the other side. Below the passenger platform there would be a momentary push switch, connected to a buzzer or light. Figure 4.1 is an illustration of this device.

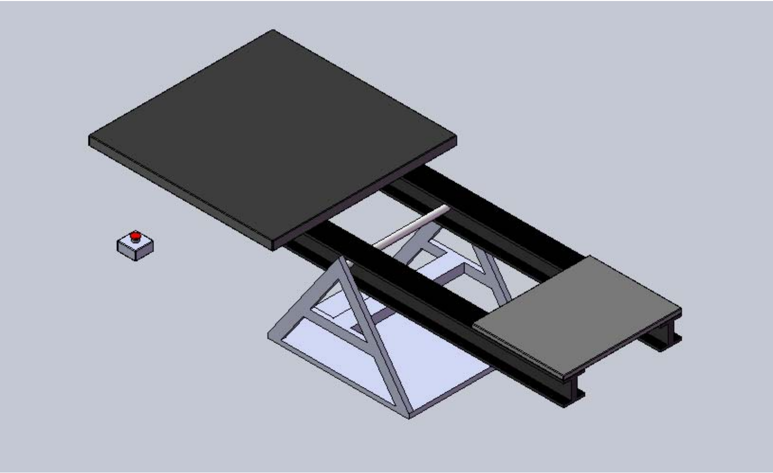


Figure 4.1: Fulcrum

Passengers would step onto the platform, and it would begin to lower. When there was more passenger weight on the platform, it would lower and push the switch, which would sound the buzzer or turn on the light to signal that a certain amount of weight was on the platform and about to board the vessel. This method would require that an employee listen for the buzzer or monitor the light and subsequently count the number of times the switch has been activated. The employee would then use the following equation to calculate the total weight on the vessel:

$$N_{Buzzer} \times W \leq M$$

Where:

N_{Buzzer}= *Number of Times the Buzzer Sounds*

W = *Weight Associated With Platform*

M= *Maximum Allowable Weight on the Vessel*

Floating Barge

Another possible solution suggested to us by Mr. Peters was the use of a floating barge to measure the weight of passengers. The floating barge would work similar to a scale. Figure 4.2 illustrates a floating barge that passengers would walk onto when boarding the vessel. The barge would have a hole in the middle with a cylinder attached. A rod would be positioned through this cylinder in the water and would be supported by its own buoyancy force. The cylinder would have multiple lines marked on it, which would represent different, predetermined weights. As people stepped onto the barge it would sink lower in the water and the rod would move up the cylinder. This system would give the vessel master a rough estimate of how much weight he or she was bringing onto the vessel.

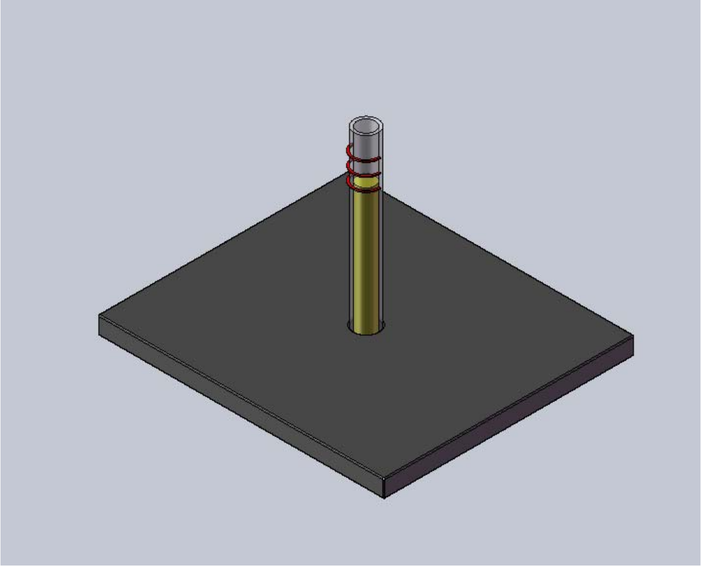


Figure 4.2: Floating Barge

It would take one employee to perform this method. The employee would count the number of passengers as they are loaded onto the barge, and then see which line the rod is closest to and record the weight associated with that line. The employee would then total the weights that he or she had collected using the following equation:

$$(N_1 \times W_1) + (N_2 \times W_2) + (N_3 \times W_3) + \bullet\bullet\bullet + (N_n \times W_n) \leq M$$

Where:

N_1= *Number of Times the Rod reaches Line 1*

N_2= *Number of Times the Rod reaches Line 2*

N_3= *Number of Times the Rod reaches Line 3*

N_n= *Number of Times the Rod reaches Line n*

W_1= *Weight associated with Line 1*

W_2= *Weight associated with Line 2*

W_3= *Weight associated with Line 3*

W_n= *Weight associated with Line n*

M = *Maximum Allowable Weight on the Vessel*

Five Gates

The Five Gates solution was another potential solution suggested to us by Mr. Peters. There would be five different gates and one extra passage. Table 4.9 defines the heights of each gate.

Table 4.9: Gate Heights based on CDC Data

Gate No.	Height (inches)
1	60
2	63
3	65
4	68
5	71
Passage	-

Table 4.10 associates a specific weight with each gate. These weights were established using data from the Centers of Disease Control. The data were sorted from shortest to tallest heights. The weights were then formulated by averaging the different ranges based on the following endpoints: 10th, 25th, 50th, 75th, 90th, and 100th percentile.

Table 4.10: Weights Associated with Each Gate

Gate No.	Weight (pounds)
1	138
2	152
3	164
4	177
5	192
Passage	211

Passengers would be asked to walk through the gate through which they most easily fit. There would be an employee stationed at each gate with one stationed at the final passage. Each employee would count the number of passengers that passed through the gate. There would then be an employee who would be responsible for taking the numbers obtained from the employees at each gate, and calculating the total weight about to board the vessel using the following equation:

$$(N_1 \times 138lbs) + (N_2 \times 152lbs) + (N_3 \times 164lbs) + (N_4 \times 177lbs) + (N_5 \times 192lbs) + (N_{Passage} \times 211lbs) \leq M$$

Where:

N_1 = *Number of passengers that pass through Gate 1*

N_2 = *Number of passengers that pass through Gate 2*

N_3 = *Number of passengers that pass through Gate 3*

N_4 = *Number of passengers that pass through Gate 4*

N_5 = *Number of passengers that pass through Gate 5*

$N_{Passage}$ = *Number of passengers that passed through the extra passage*

M = *Maximum Allowable Weight of the Vessel.*

4.2 Analysis of Possible Solutions

In order to determine which solutions were most practical, we analyzed each of them for efficiency, ease of implementation, enforceability, and accuracy. The first three criteria were assessed by comparing qualitative data. We quantitatively analyzed the accuracy of non-physical solutions by simulating loading conditions on passenger vessels.

4.2.1 Efficiency

In order to determine the impact that a possible solution might have on a vessel company's operation, we qualitatively analyzed each for efficiency. We defined efficiency as the amount of time it takes for the vessel company to determine if their vessel is overloaded. If the solution takes a significant amount of time then it is considered inefficient since it might delay the vessel's departure time and negatively affect the rest of the company's operation. Table 4.11 lists each of our possible solutions and the factors that affect their efficiency.

Table 4.11: Efficiency Factors

Solution	Count Passengers	Inquire Passengers	Calculations	Judge Passengers	Refer to Table	Monitor	Loading
Asking Passenger Weight	X	X	X				
Number Approx.	X		X	X			
Estimations by Size	X		X	X	X		
Load Marks	X					X	
CDC Weights	X				X		
USCG Proposed Weight	X						
FAA Standard Weights	X			X			
FAA Segmented Weights	X				X		
Scales	X		X				X
Fulcrum	X		X				X
Floating Barge	X		X				X
Five Gates	X		X			X	

In each of our possible solutions, counting passengers is required. This is because the number of passengers on a vessel always needs to be known to ensure that the vessel has enough available lifesaving equipment and that the vessel does not exceed the maximum number of passengers permitted by their Certificate of Inspection. The number of passengers allowed on a vessel by the certificate of inspection is determined by lifesaving, security, and other general safety factors. Counting passengers is required under the current Coast Guard regulations and should have a minimal effect on a passenger vessel company's operation in regards to time.

When determining whether a vessel is overloaded by asking passengers their weight, there is time required to speak with each passenger and then record the weight they provide. When determining the total passenger weight of a vessel with more than twenty-five passengers, this may become very time consuming and hurt the efficiency of the vessel company's operation. Problems can also arise when passengers boarding vessels do not speak English or do not speak English well. This could take more time so there needs to be an assumed average weight to use instead.

In eight of our possible solutions calculations are required to determine the amount of passenger weight getting onto a vessel. In these cases, calculations must be performed as each passenger or group of passengers get onto the vessel. In the case of the Number Approximation solution, this can be done by hand. In all other cases a calculator or a computer program needs to be used to perform calculations. If these solutions were installed into a computer ticketing program then this time cost would be minimal. Otherwise the time cost is only practical for applications when there are twenty-five passengers or less.

For the Number Approximation and Estimations by Size solutions, an employee at the passenger vessel company would be required to judge each passenger that will be boarding a vessel. For the Number Approximation solution, this is quicker and should only take a few seconds to determine whether a passenger is a man, woman, or child, and if their luggage is worth weight consideration. The Estimations by Size solution might take a few more seconds to judge since the employee needs to fit each passenger into one of nine different categories. The Number Approximation solution can be easily integrated into a computer ticketing system but the Estimations by Size solution cannot. This makes the Estimations by Size solution impractical for vessels carrying more than twenty five passengers.

Two of our possible solutions include time where an employee needs to refer to a table. For each passenger this should only take a few seconds but needs to be accounted for. The tables used in the CDC Weights and FAA Segmented Weights solutions can be implemented into a computer ticketing program making the solutions more efficient. Despite a small time requirement when done by an employee, these two methods could be used for vessels carrying 149 people.

The Load Marks and Five Gates solutions need an employee to monitor their proficiency. Load marks need to be watched so that they do not drop below the surface of the water. In the Five Gates solution, monitoring is more complicated since employees need to make sure that passengers are using the system properly, and they also need to count the number of people that walk through each gate. The Five Gates solution is difficult to monitor but it can be used for any size vessel as can Load Marks.

The Fulcrum, Scale, and Floating Barge solutions all have to take into account the time required to load and unload passengers. Company employees will have to direct passengers onto and off of different platforms for each one of these solutions. This process will take time and might cause these solutions to be very inefficient when needing to direct a large number of people.

Overall, the USCG Proposed Weight solution is most efficient because the time required to determining whether the vessel is overweight is negligible. Load Marks are also very efficient since they only require counting passengers and monitoring the load mark. Using the CDC

Weights and FAA Segmented Weights solutions are also very efficient and require minimal time. These two solutions, along with the Number Approximations and Asking Passengers their Weight, can be extremely efficient and practical for all size vessels if they are implemented using a computer system.

4.2.2 Ease of Implementation

Another criterion in our analysis was the ease in which each solution could be implemented by different vessel companies. We defined the ease of implementation as the amount of time and resources needed to install each solution. Some solutions involved the design of a mechanical/electrical system, while others involved the training of personnel and buying of inexpensive supplies. Table 4.12 lists each solution and its respective implementation factors.

Table 4.12: Ease of Implementation Factors

Solution	Need USCG Approval	Extra Dock/ Water Space	Cost to Build/Buy Device	Cost Minor Supplies	Current or New SST	Employee Training
Asking Passenger Weight	X			X	X	
Number Approx.	X			X	X	X
Estimations by Size	X			X	X	X
Load Marks	X			X	X	
CDC Weights	X				X	
USCG Proposed Weight	X			X	X	
FAA Standard Weights	X			X	X	
FAA Segmented Weights	X				X	
Scales	X	X	X	X	X	
Fulcrum	X	X	X	X	X	
Floating Barge	X	X	X	X	X	
Five Gates	X	X	X	X	X	

For all of these solutions to be implemented, the maximum allowable weight on a passenger vessel needs to be known. We have concluded that two processes can be used to determine this weight. The first process is a result of the U.S. Coast Guard's Proposed Rule Change, which is to increase the average passenger weight used in calculations and stability tests to 185 pounds. According to this proposed rule, each passenger vessel must undergo a new Simplified Stability Test (SST) to determine the maximum allowable weight for that vessel. The problem with this process is that it would take a few years to re-test every vessel and will thus delay the implementation of a new method to determine when a vessel is overloaded.

The second process that we developed is to calculate the maximum allowable weight on a vessel based on its current SST. The equation would be as follows:

$$N_{SST} \times AVG = M$$

Where:

N_{SST} = *Number of Passengers Allowed on the vessel's current SST*

AVG = *Average Weight associated with the Vessel (Normally 160lbs)*

M = *Maximum Allowable Weight on the Vessel*

This process was developed for the vessel companies that might not be able to afford a new SST and for vessels that operate with a maximum passenger number that is lower on their Certificate of Inspection (COI) than on their current stability letter.

Depending on which process an owner prefers to evaluate a vessel, the ease of implementation will vary. If an owner prefers a vessel undergo a new SST, the Coast Guard will need to specify a date when all new SSTs need to be completed. On the other hand, if an owner prefers a vessel to base its maximum weight off of its current stability letter, a solution could be implemented immediately.

With the option of so many solutions and wide variety of types of vessels, passenger vessel companies would need to inform the Coast Guard of which solution is being used. The Coast Guard would then approve the solution based on whether it is acceptable for the given vessel and its service. To do this it should be mandated that the Coast Guard approve the solution being used to monitor or manage passenger weight after a system has been installed, but before it is initially used. Though this will increase the time it takes to implement the solution, it will help assure passenger safety.

An underlying problem with implementing some of our solutions is the requirement of dock space. For many vessel companies, dock space is very limited and sometimes shared. This lack of dock space could make it difficult, if not impossible, to implement some of our possible solutions. Another problem concerning dock space is that some companies rent the space where their vessel is docked. They therefore may not have the right to place any type of measuring device on the dock, again making it impossible to implement some of our solutions. See Appendix M for some examples of dock space we have seen.

When analyzing our solutions, we established that implementing almost all of the possible solutions required some type of expense. The degree of expense depended on the solution itself. For solutions such as the Fulcrum, Scales, Floating Barge, and Five Gates, the expense could be quite high. All of those solutions except the Scales involve design, construction and supply costs. (The scales involve the cost of the scales and having them calibrated every month.) In the case of the Load Marks, the only expense would be buying the paint and paint brushes. For the rest of the solutions, the expense would include buying pens/pencils, paper, or a calculator, which would be minimal. If a company wanted to use a computer program, a slightly greater expense would be incurred. The three possible solutions that would not involve any added cost would be to use the CDC Weight, the FAA Segmented Weight, or the USCG Proposed Weight.

A minor requirement that may delay the implementation of a few possible solutions is the time needed to train employees. Employee training is only necessary for the Number Approximation and Estimates by Size solutions. In these situations, employees are being trained to observe people and learn how to best estimate which category each passenger would be classified. This could be time consuming and could cost the employer money depending on whether he or she pays the employees for the time they spend being trained.

The ease of implementation of each solution depends upon the complexity of each solution. Through our analysis we found that the Asking Passengers their Weight solution would be the easiest to implement. This is because it can be easily and cheaply applied. If tickets are bought online the computer program used to manage the sale of tickets could be adjusted to have the program calculate the total weight. If tickets are sold at a ticket booth, the employee can ask passengers their weight and keep a running total as tickets are sold. This requires the least amount of installation time or money, and therefore is easiest to implement.

4.2.3 Enforceability

When performing our analysis we also compared each solution based on its enforceability. We defined enforceability as the ability of a vessel company to prevent overloading during its ticket selling process. This criterion was made to evaluate the human factor involved in possibly asking a passenger(s) to exit a vessel when it is overweight.

These situations could arise when the total passenger weight is calculated after a passenger has purchased a ticket. We decided that this was an important aspect to assess because it would not be beneficial for vessel companies to ask passengers to exit a vessel and then refund the money. This problem could cause further controversy if the tickets were not numbered because the vessel company would not know which passenger(s) was the last to purchase a ticket. This would force an employee to choose a passenger that would have to leave the vessel without a specific reason.

Solutions that were easy to enforce avoided these situations. They did this by calculating the total passenger weight during the ticket selling process. By determining the weight this way, no employee would be forced into the undesirable task of asking a passenger to exit the vessel and then refunding his/her money. Table 4.13 compares the solutions based on enforceability factors.

Table 4.13: Enforceability Factors

Solutions	Weight Known As Tickets Are Sold	Keep Records
Asking Passengers Their Weight	X	X
Number Approximation	X	X
Estimations by Size		X
Load Marks		X
CDC Weights	X	X
USCG Proposed Weight	X	X
FAA Standard Weights	X	X
FAA Segmented Weights	X	X
Scales		X
Fulcrum		X
Floating Barge		X
Five Gates		X

Most passenger vessels would be affected by these situations if they used a solution that calculated the total passenger weight as passengers boarded. The passenger vessels that would not be affected are ferries and water taxis. They operate continuously, and passengers could use their tickets to board the next ferry or water taxi if the weight limit was met.

We also decided that it would be reasonable to have vessel companies keep records of the number of passengers and the total calculated passenger weight. Keeping this information would hold vessel masters accountable for their decisions regarding passenger weight. Also, in the case of an accident, officials could refer to these records in order to possibly dismiss passenger overloading as a contributing factor.

The easiest solutions to enforce would be the CDC Weights, USCG Proposed Weight, and the FAA Segmented Weights. These are better than the other solutions because employees would have a table that allows them to easily assess potential passengers as either a male or female and would not need to worry about the number of children.

The solutions that would not be easy to enforce involve selling tickets to passengers without being able to keep track of the passenger weight. These solutions included Estimations by Size, Load Marks, and all of the Physical Solutions. Thus, for vessels carrying a maximum number of passengers, there is a chance that the passenger limit may be exceeded before all passengers have boarded, resulting in an employee needing to inform a passenger that he/she cannot get on the vessel because the vessel is at its maximum allowable weight.

4.2.4 Accuracy

For evaluating accuracy, we created a computer program that would select a random sample of the biometrics for a specified number of passengers. We utilized the biometric data that was used to produce the National Health Statistics Report to create a database that could be accessed by our computer program. We were then able to simulate eighteen different loading scenarios based on the following factors: number of passengers, age range, and gender ratio. A diagram of this software can be seen in Appendix L.

We conducted thirty simulations for twenty-five, forty-nine, and 149 passengers to accumulate ninety simulations. We chose these passenger numbers because twenty-five passengers is a small Subchapter T passenger vessel, forty-nine passengers is an average-sized Subchapter T passenger vessel, and 149 passengers is the maximum number of passengers allowed on a Subchapter T passenger vessel. We also learned from Coast Guard officials that there are a lot of vessels that are certificated to carry 49 and 149 passengers because they want to avoid additional regulations that apply when they carry more.

For each number of passengers, we conducted fifteen simulations for two different age ranges: older than two years and older than twenty-one years. We chose these ages because passengers older than two years represent the entire population on vessels such as ferries or water taxis. Passengers older than twenty-one years represent the population on gambling vessels.

The age ranges were then broken down into three groups of five simulations: all male, all female, and mixed. We were able to evaluate the extreme situations that could occur on some vessels. Appendix N contains the results of our simulations.

Tables 4.14 through Table 4.25 were produced once all simulations were completed. These tables provide average total passenger weights that were calculated using our simulations. Each solution’s total weight is related to weights of passengers without clothing because this is how the National Health Statistics Report determines a person’s weight. Simulations were averaged based on the parameters described in the table’s title. Each table evaluated the average total passenger weight for every applicable solution.

The Scales, Fulcrum, Asking Passengers their Weight, and Load Marks solutions are not included in our simulations because they cannot be easily modeled by our simulator so we analyzed them qualitatively. For the purposes of our study we assumed that scales would be the most accurate solution since they would be able to estimate the average total weight within a few pounds of the actual total weight. Inaccuracies in scales can be found if they are not calibrated properly.

In the Fulcrum solution, the accuracy will vary depending on the amount of weight on the opposite side of the fulcrum. The larger the counter-weight, the more accurate the solution will be. The inaccuracies of this solution come when a person steps on the fulcrum and pushes it past the tipping point. In this situation the actual amount of weight that person is contributing is unknown.

The inaccuracies from Asking Passengers their Weight are found in the error between the weight a passenger gives and what their actual weight is. The accuracy of Load Marks is dependant upon the size of the vessel and the weather conditions. If the weather conditions are poor then the load mark is difficult to read and less accurate. The Load Marks solution also has poor accuracy because a change in passenger weight usually results in an insignificant change in position.

For the Floating Barge solution, the level of accuracy will be dependent upon the dimensions of the barge. To determine how accurate the Floating Barge solution is, we calculated the weight change that would be associated with a certain amount of displacement for two barges with different dimensions. We assumed that an employee at the vessel company would be able to accurately read the pole in the center to ¼ inch of accuracy. For a barge with dimensions ten feet by fifteen feet, every ¼ inch of immersion is equal to 200 pounds. For a barge with dimensions fifteen feet by twenty five feet, ¼ inch of immersion is equal to 490 pounds. These values were found by using the area of the barge and the volume of water displaced when a test weight is applied to the barge to calculate the vertical displacement of the barge. The larger the area of the barge is, then the less accurate it will be.

We evaluated each solution based on its total difference, standard deviation, and success rate. Total difference is defined as the difference for specific loading scenarios between the average total weight that a solution calculated and the actual average total weight. Standard deviation is a mathematical value that is used to determine how close to the average total weight most of the calculated weights are. A small standard deviation means that the calculated weights are relatively close to the average total weight; however, a large standard deviation means that the calculated weights are not close to the average total weight.

Success rate was determined by the percentage of conservative calculations. Conservative is defined as the event when a solution calculates a total weight that is larger than the actual total weight. We counted the number of times this happened for each solution and loading scenario. We have highlighted the cells with the lowest total difference and the highest success rate in light blue. The cells with the second lowest total difference and the second highest success rate are highlighted in light gray.

Table 4.14 examines all simulations of passengers regardless of a passenger's age or gender. This table does not contain the average of the ninety simulations or the standard deviation because different sizes of vessels are included and these values would not be valid factors to analyze. From this table, we are able to establish a benchmark of 73% for success rate because this is the value that corresponds to the U.S. Coast Guard Proposed Weight. Therefore, if a solution's success rate is relatively close to 73% it is very comparable and then the number of passengers becomes a major factor in deciding which solution is better.

Table 4.14: Accuracy of All Vessels

90 Simulations	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Success Rate	51%	73%	76%	59%	97%	73%	66%	31%

Table 4.15 examines each solution based on a vessel carrying twenty-five passengers. Thirty simulations met this criterion, and it can be seen that the FAA Segmented Weights solution was the most successful and the Old USCG Weight solution had the lowest total difference.

Table 4.15: Vessels Carrying 25 Passengers

30 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	3,938	3,950	4,450	4,500	3,994	4,926	4,089	4,304	3,874
Total Difference (lbs.)		12	512	562	56	988	151	366	-64
Standard Deviation (lbs.)		0	0	312	538	208	592	177	611
Success Rate		50%	73%	70%	60%	100%	70%	60%	40%

Table 4.16 and Table 4.17 concentrate on the age ranges for vessels carrying twenty-five passengers. For vessels carrying passengers older than two years old, most of the solutions are 100% successful, but the total differences are high. For example, the U.S. Coast Guard's Proposed Weight solution provided nearly an extra forty-five pounds per passenger, which is extremely high. On the other hand, for vessels carrying passengers older than twenty-one years old, more than half of the solutions are less than 50% successful, but the total differences are low.

Table 4.16: Vessels Carrying 25 Passengers, Ages 2 and Older

15 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	3,336	3,950	4,450	4,501	3,526	4,927	3,591	4,192	3,364
Total Difference (lbs.)		614	1,114	1,165	190	1,591	255	857	29
Standard Deviation (lbs.)		0	0	318	284	212	271	105	341
Success Rate		100%	100%	100%	80%	100%	87%	100%	67%

Table 4.17: Vessels Carrying 25 Passengers, Ages 21 and Older

15 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	4,540	3,950	4,450	4,499	4,462	4,925	4,586	4,416	4,384
Total Difference (lbs.)		-590	-90	-41	-78	385	46	-124	-156
Standard Deviation (lbs.)		0	0	317	222	211	349	165	314
Success Rate		0%	47%	40%	40%	100%	53%	20%	13%

Table 4.18 examines vessels carrying forty-nine passengers. Since most of the total differences (100-200 lbs., 600-1,000lbs.) and success rates (70% - 77%) are close to each other, it is difficult to decide which is the most accurate. We decided that in order to determine the most accurate solution, one should view the success rate first, and then make sure that the total difference is acceptable. Therefore, for vessels carrying forty-nine passengers, Number Approximations is the best solution to use because it is 70% successful and provides on average an extra four pounds per passenger.

Table 4.18: Vessels Carrying 49 Passengers

30 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	7,869	7,742	8,722	8,824	7,895	9,312	8,062	8,479	7,730
Total Difference (lbs.)		-127	853	955	26	1,442	193	610	-140
Standard Deviation (lbs.)		0	0	615	963	410	1,107	336	1,019
Success Rate		53%	73%	77%	60%	93%	70%	70%	40%

Table 4.19 and Table 4.20 examine vessels carrying forty-nine passengers in more-depth. We start to see a trend that for vessels that include all ages; the success rate is 100% for most of the solutions but the total difference is also high. We also see a trend for vessels that include only passengers older than twenty-one; the success rate is low, and the total difference is negative for half of the solutions, which is not a good thing.

Table 4.19: Vessels Carrying 49 Passengers, Ages 2 and Older

15 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	6,949	7,742	8,722	8,817	7,036	9,310	7,120	8,302	6,854
Total Difference (lbs.)		793	1,773	1,868	87	2,361	171	1,353	-95
Standard Deviation (lbs.)		0	0	625	385	417	401	222	456
Success Rate		100%	100%	100%	67%	100%	67%	100%	40%

Table 4.20: Vessels Carrying 49 Passengers, Ages 21 and Older

15 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	8,789	7,742	8,722	8,831	8,754	9,313	9,004	8,656	8,605
Total Difference (lbs.)		-1,047	-67	42	-35	524	214	-133	-185
Standard Deviation (lbs.)		0	0	627	439	418	690	343	548
Success Rate		7%	47%	53%	53%	87%	73%	40%	40%

The next three tables deal with vessels carrying 149 passengers. In Table 4.21, the two solutions that have the lowest total difference also have the lowest success rates. The CDC Weights solution was determined to be the most accurate because it had the second highest success rate and it also provided an extra eighteen pounds per person, which we felt was an acceptable number given the large number of passengers.

Table 4.21: Vessels Carrying 149 Passengers

30 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	24,072	23,542	26,522	26,776	24,216	28,065	24,679	25,743	23,680
Total Difference (lbs.)		-530	2,450	2,704	144	3,992	607	1,671	-392
Standard Deviation (lbs.)		0	0	1,858	2,631	1,330	3,118	965	2,927
Success Rate		50%	73%	80%	57%	97%	80%	67%	13%

Table 4.22 and Table 4.23 examine the age ranges for vessels carrying 149 passengers. The trend continued with these vessels as well. The Old U.S. Coast Guard Weight is the most accurate for all ages because it was 100% successful and the total difference was acceptable. The most accurate for passengers older than twenty-one years old was the FAA Segmented Weights solution because it was 93% successful and provided about nine extra pounds per passenger.

Table 4.22: Vessels Carrying 149 Passengers, Ages 2 and Older

15 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	21,399	23,542	26,522	26,765	21,859	28,121	22,053	25,238	21,180
Total Difference (lbs.)		2,143	5,123	5,366	460	6,722	654	3,839	-219
Standard Deviation (lbs.)		0	0	1,891	823	1,290	1,015	647	1,168
Success Rate		100%	100%	100%	87%	100%	93%	100%	20%

Table 4.23: Vessels Carrying 149 Passengers, Ages 21 and Older

15 Simulations	Actual Weight	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Average	26,745	23,542	26,522	26,787	26,573	28,008	27,305	26,248	26,181
Total Difference (lbs.)		-3,203	-223	42	-172	1,262	560	-497	-564
Standard Deviation (lbs.)		0	0	1,891	1,323	1,412	2,080	982	1,727
Success Rate		0%	47%	60%	27%	93%	67%	33%	7%

The last two tables split the simulations into the two age ranges. From Table 4.24, it is difficult to determine which solution is the best for vessels carrying passengers older than two years. From Table 4.25, we were able to easily determine that the FAA Segmented Weights solutions significantly outperformed all of the other solutions listed in the table.

Table 4.24: Vessels Carrying Passengers Ages 2 and Older

45 Simulations	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Success Rate	100%	100%	100%	78%	100%	82%	100%	42%

Table 4.25: Vessels Carrying Passengers Ages 21 and Older

45 Simulations	Old USCG Weight (160lbs.)	USCG Proposed Weight (178lbs)	CDC Weights	FAA Standard Weights	FAA Segmented Weights	Number Approx.	Estimates By Size	Five Gates
Success Rate	2%	47%	51%	40%	93%	64%	31%	20%

From researching weight monitoring methods from the FAA, talking with experts from the U.S. Coast Guard, and interviewing representatives from passenger vessel companies, we were able to establish twelve possible solutions. These solutions were divided into three categories: Weight Estimation Methods, Average Weight Methods, and Physical Methods. As a result of our analysis, we determined which solutions were most efficient, enforceable, easy to implement, and accurate. In our next chapter these results are summarized and our recommendations based off of these results are presented.

5.0 Conclusions and Recommendation

The goal of our project was to recommend an effective solution that would allow vessel masters to know if their vessels have surpassed their maximum allowable weight. Efficiency, ease of implementation, enforceability, and accuracy were used to analyze our twelve possible solutions. Each solution had both positive and negative aspects based on these criteria. Our recommendations were determined by different situations that we decided would occur most frequently. We also provide recommendations for further research that we believe may lead to more accurate and more feasible solutions than the ones we recommend.

5.1 Conclusions

In this section we provide a summary of the results we obtained from analyzing our twelve possible solutions using our four analysis criteria. The solutions that best fit each criterion are outlined as well as the solutions that scored very high in each area. It was from these results that our final recommendations were chosen.

5.1.1 Efficiency

We defined efficiency as the amount of time it takes for the vessel company to determine if their vessel is overloaded. A solution is inefficient if it takes too much time to use, delays the departure and arrival time of the vessel, or affects the basic operation of the business.

Our analysis showed that the USCG Proposed Weight solution is the most efficient. This is because it only involves counting the number of passengers that are boarding a vessel, making the amount of time required for this solution negligible. Load Marks are also very efficient since they only require counting passengers and monitoring a load mark on the side of the vessel. The CDC Weights and FAA Segmented Weights solutions are very efficient as well because they require minimal time. These solutions, along with the Number Approximations and Asking Passengers their Weight, can be extremely efficient and practical for all size vessels if they are incorporated into a computer system.

5.1.2 Ease of Implementation

We defined ease of implementation as the amount of time and resources needed to install a solution. A solution that would involve a mechanical or electrical device would not be easy to implement because it would require both time and money to design and construct. On the contrary, a solution that requires an employee counting passengers would be easy to implement.

We established that Asking Passengers their Weight would be the easiest solution to implement. With this solution, the passenger vessel company would sum the weights of each passenger. This calculation could be done with a calculator or by a computer program. This was the easiest solution to implement because it requires the least amount of time, money, and resources to implement. We also found that the CDC Weights and FAA Segmented Weights solutions are very easy to implement since they require very little time, money, and resources. These two solutions require an employee to refer to a table in order to determine if the vessel is overweight, using the number of men and women that are boarding the vessel.

5.1.3 Enforceability

We defined enforceability as the ability of a vessel company to prevent overloading during its ticket selling process. A solution was easy to enforce if it decreased the chance of a company overbooking and possibly needing to ask passengers to exit the vessel.

Our analysis showed that CDC Weights, USCG Proposed Weight, and FAA Segmented Weights solution were the easiest to enforce. They were the easiest to enforce because the most extensive requirement for determining passenger weight was counting males and females. This means that the maximum various ratios of males and females would be known before tickets are sold. Thus, the vessel company could stop selling tickets when these passenger counts are reached.

5.1.4 Accuracy

Accuracy was one of the main components of our project. Each solution was assessed based on three accuracy factors: total difference, standard deviation, and success rate. Total difference and success rate were analyzed first, and when multiple solutions were similar in these categories, we then referred to the standard deviation to make our final decision.

The USCG Proposed Weight, 73% success rate over all simulations, did not evaluate as well as would be expected; however, there is a reason. We created eighteen different loading scenarios, and twelve of the loading scenarios were extreme situations. This meant that of our ninety simulations: all males (extreme) accounted for thirty simulations (33.3%), all females (extreme) accounted for thirty simulations (33.3%), and a mix of males and females accounted for thirty simulations (33.3%). For vessels carrying passengers' ages two years and older, we saw that this solution had a 100% success rate. For vessels carrying passengers' ages twenty-one years and older, we saw that the solution was never successful for all males, 100% successful for all females, and 40% successful for a mix of males and females.

The most accurate solution for vessels carrying twenty-five passengers was Number Approximations. This was most accurate because for both age ranges it had low total differences (255 lbs. and 46 lbs.) and the second highest success rates (87% and 53%). The standard deviations were low, which meant that this solution was not calculating a wide-range of weights.

We determined that the Number Approximations solution was also the most accurate for vessels carrying forty-nine passengers. It was the most accurate because when carrying passengers' ages two years and older the other solutions were providing too much safety margin, whereas this solution was providing on average eight pounds per passenger. Its success rate was consistent, and its standard deviation was acceptable.

For vessels carrying 149 passengers, we concluded that the CDC Weights solution was the most accurate. It provided enough safety margins for vessels carrying passengers' ages two years and older, which would be needed when carrying 149 passengers. The success rate for vessels carrying passengers' ages twenty-one years and older was acceptable because the number of these voyages are limited.

5.2 Recommendations

As a result of our analysis, we determined effective solutions that allow vessel masters to know whether their vessel has surpassed its maximum allowable weight before departing on a voyage. We also discovered areas of our research that could be expanded upon and possibly lead to better solutions for determining the total passenger weight that boards a passenger vessel.

5.2.1 Best Solutions to Prevent Overloading

Since passenger vessel companies operate their business in various ways depending on the vessel's size and type, we have devised recommendations for vessels that carry up to twenty-five, forty-nine, and 149 passengers. We chose these passenger counts because twenty-five passengers is a small passenger vessel in Subchapter T, forty-nine passengers is an average passenger vessel in Subchapter T, and 149 passengers is the maximum number of passengers allowed in Subchapter T. There are also a lot of boats that are certificated at a maximum of forty-nine passengers and 149 passengers since they will be subject to extra regulations if they exceed those limits.

For vessels that carry passengers older than twenty-one years old, we recommend the FAA Segmented Weights solution. This solution involves referring to a table that associates a weight that corresponds to the number of men and women on the vessel (See Section 4.1.2 for a more in-depth description.) This solution ranked very high in all of our criteria. Since a passenger count is the only requirement, switching from the current method to this solution will not affect the efficiency, implementation, or enforceability. Based on the information from the different loading scenarios, it can be seen that the FAA Segmented Weights outperforms the current method in both total difference and success rate. The FAA Segmented Weights solution is successful on 93%(42/45) of the simulations that contain passengers older than twenty-one years old, while the current method is only successful on 2% (1/45) of the simulations. Total difference was also significantly better because the FAA Segmented Weights solution overestimated while the current method underestimated.

For passenger vessels carrying up to twenty-five passengers, we recommend that the FAA Standard Weights solution is the best. This solution is not very efficient for large passenger counts, but it is still acceptable for twenty-five passengers due to its simplicity. This solution's accurate was acceptable with a total difference of 56 pounds and success rate of 60%. There was a significant increase in accurate when a safety margin of five pounds per passenger was added: total difference of 181 pounds and a success rate of 87%.

For vessels carrying up to forty-nine passengers, we recommend using the Number Approximation solution. This solution requires simple calculations that can be done by hand or by a computer ticketing system. It is easy to enforce and implement since no physical devices are necessary. It produced very consistent total differences and success rates when determining its accuracy.

For vessels carrying up 149 passengers, we recommend that the best solution was the U.S. Coast Guard's Proposed Weight of 185 pounds. We decided that this was the best solution because there was no change in efficiency, implementation, or enforceability. The remaining factor of accuracy had a precision of 2,450 pounds (sixteen pounds per passenger) and success rate of 73%, which were deemed to be acceptable values.

5.2.2 Further Research

When analyzing our possible solutions for accuracy, we discovered that the Five Gates solution for assessing passenger weight came very close to estimating the actual passenger weight during most of our simulations. This solution, which estimates each passenger's weight based on his/her height, was determined to conservatively estimate the amount of weight on a vessel only 31% of the time. Despite this low success rate, we noticed that it had the lowest total difference in four of the nine different loading situations and in the other five situations was also relatively low. We believe that if a safety margin of a few pounds were added to each of the average weights used for the five different height ranges, the success rate of this solution will drastically increase.

Besides the poor success rate, the Five Gates solution did not become a recommended solution because it was not easy to implement. Although we have determined that the method of associating average weights with height ranges can be a very accurate way to estimate passenger weight, the physical solutions that we suggested are not very practical. With further research, it may be possible for the Coast Guard to develop a solution that is more accurate than our current recommendations using the relationship between height and weight. We recommend that the Coast Guard investigate practical methods for applying the relationship between height and weight so that a better solution may be created to prevent passenger vessels from becoming overloaded.

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Appendix A: Mission of Agency

The United States Coast Guard is one of the five branches of the United States Military and is therefore a government run organization. Its main objectives "are to protect the public, the environment, and U.S. economic and security interests in any maritime region in which those interests may be at risk, including international waters and America's coasts, ports, and inland waterways"(United States Coast Guard, 2007, "Missions"). The Coast Guard is broken down into five divisions of operations: Maritime Safety, Maritime Security, Maritime Mobility, National Defense, and Protection of Natural Resources. The Coast Guard's motto is Semper Paratus—(Always Ready), and the service is always ready to respond to calls for help at sea (United States Coast Guard, 2007, "About Us").

The Coast Guard has three branches: The Chief of Staff, Atlantic Area Commander, and Pacific Area Commander (United States Coast Guard, 2007, "Organization"). All three branches report directly to the Commandant and Vice Commandant (Figure A.1). In total, the Coast Guard has approximately 40,150 members on active duty.

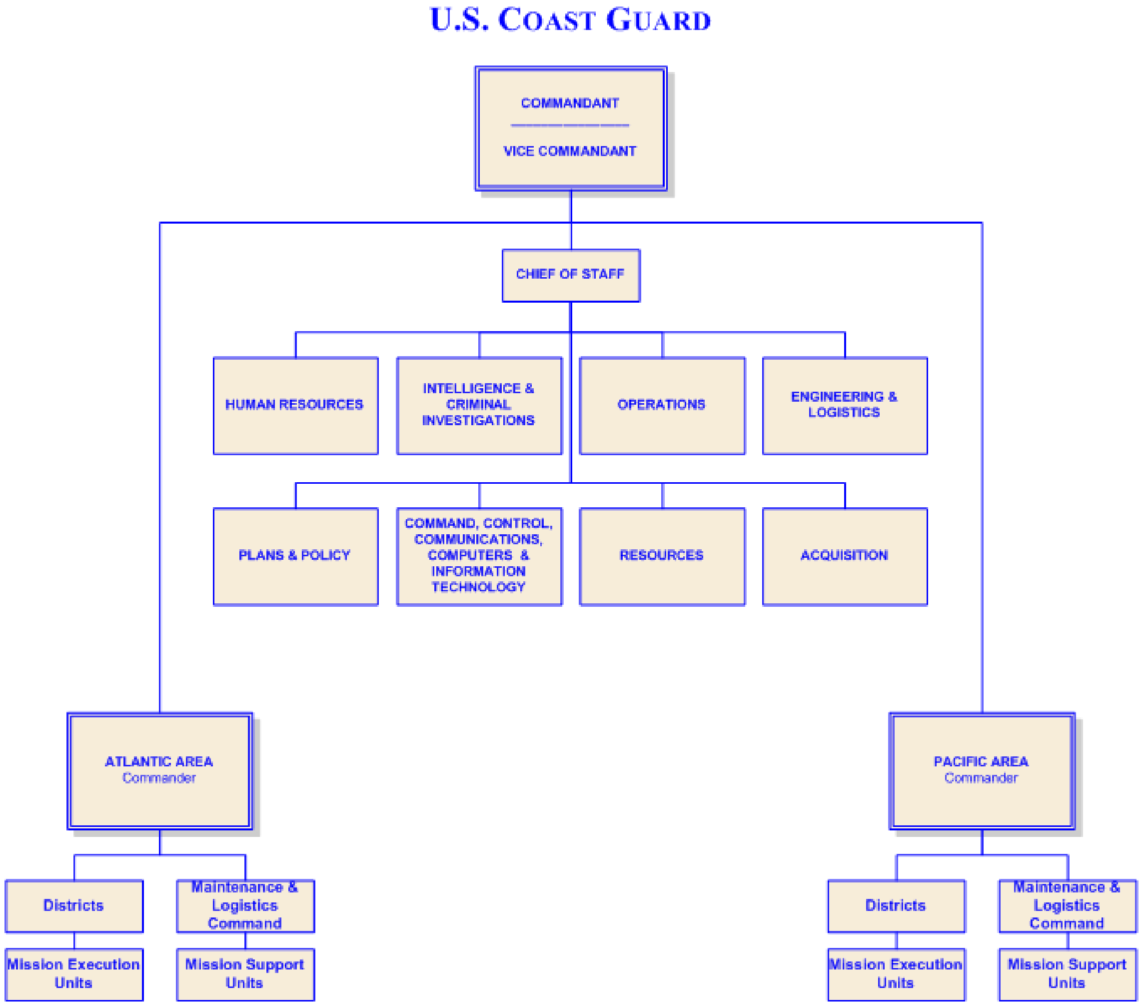


Figure A.1: U.S. Coast Guard Division of Labor Organization Chart (United States Coast Guard, 2007, "Organization")

The mission of the Maritime Safety Division is to "Eliminate deaths, injuries, and property damage associated with maritime transportation, fishing, and recreational boating" (United States Coast Guard, 2007, "Missions"). Fifty percent of the members of the Marine Safety Division are civilians while the other fifty percent are military. Our project of Passenger Vessel Weight Overloading was based in the Maritime Safety Division, but more specifically in the Office of Design and Engineering Standards under the Director of Commercial Regulations and Standards. At the Coast Guard Headquarters, the Commercial Regulations and Standards is responsible for making and updating the regulations that all water vessels must meet and comply with (M. Byrd, 2008). More specifically, the Office of Design and Engineering Standards publishes regulations on how ships are built and the requirements they must meet in order to sail. Our group mainly worked with people in the Naval Architecture and Systems Engineering Department.

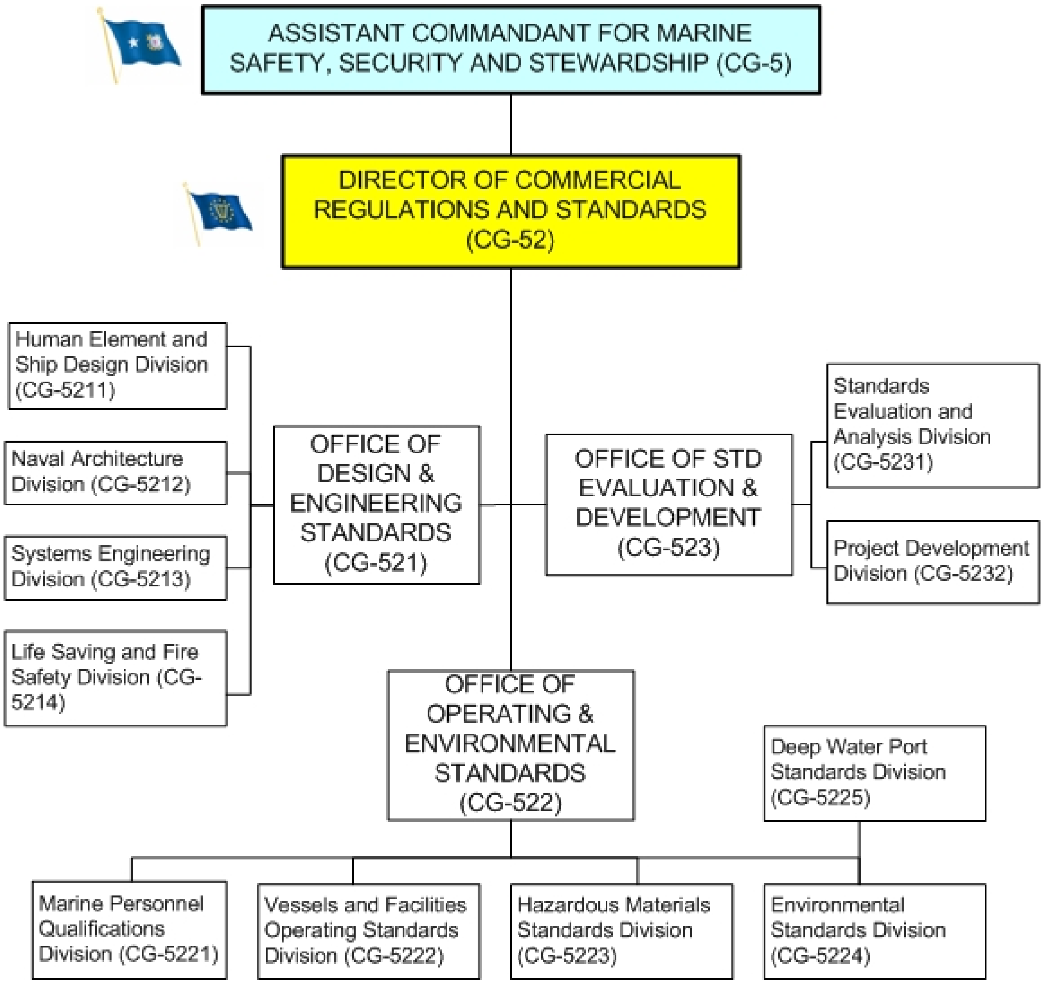


Figure A.2: Organization Chart of Commercial Regulations and Standards Division (United States Coast Guard, 2008, "Director of Commercial Regulations and Standards")

The capsizing and sinking of passenger vessels due to inaccurate weight calculations is an important issue that the Coast Guard should try to solve. This is such a significant issue because the capsizing and sinking of these vessels has not only led to their loss, but to passenger casualties as well. As stated in their mission, it is the duty of the Coast Guard to reduce the controllable causes of deaths, injuries, and property damage related to maritime transportation. Therefore, it is imperative that this issue be resolved.

Appendix B: Definitions

Amphibious Vessel- also known as a DUKW, is a 2.5-ton, six-wheel amphibious truck used in World War II by the U.S. Army and Marine Corps. Today, many of these WWII vessels are used as tour vessels that drive passengers through cities and towns along with giving water tours as well (DUKW, 2008).

Charter Fishing Vessels- any vessel, boat, ship, or other craft that is equipped and used for fishing or in support of such activity. A Charter Fishing Vessel is a privately owned vessel, which has a main purpose of providing private fishing excursions, and is not used for commercial fishing (Fishing Vessel, 2008).

Commandant: the Commandant, U.S. Coast Guard, Washington, DC 20593-0001 (Office of Federal Register National Archives and Records Administration, 2004).

Cruise Vessel: a passenger ship built or used for pleasure cruises, usually taking passengers on an extended cruise (Cruise Ship, 2008).

Diving Vessel: a vessel whose sole use is to provide transportation for diving trips. This can be any type of vessel that contains not only diving equipment to be used during the diving excursion, but also equipment that can be used in emergencies that are diving related (Dive Vessel Profiles, 2008).

Excursion Vessel: any vessel whose purpose is to make a short trip, usually for a special purpose and with the intention of a prompt return (Excursion, 2008).

Exposed Waters: are waters that are more than 20 nautical miles from a harbor of safe refuge (Office of Federal Register National Archives and Records Administration, 2004).

Ferry: is a vessel that:

1. operates in other than ocean or coastwise service;
2. has provisions only for deck passengers or vehicles or both;
3. operates on a short run on a frequent schedule between two points over the most direct water route; and
4. offers a public service of a type normally attributed to a bridge or tunnel (Office of Federal Register National Archives and Records Administration, 2004).

Master: a person holding a valid license that authorizes that person to serve as a master of a passenger vessel (Office of Federal Register National Archives and Records Administration, 2008).

Operator: the person or entity who provides operational instructions to and receives reports from the master of the vessel and is responsible for the vessel's maintenance and repair, schedule of operations, crewing, etc (Office of Federal Register National Archives and Records Administration, 2008).

Owner: the person or entity holding title to the vessel (Office of Federal Register National Archives and Records Administration, 2008).

Partially Protected Waters: waters that are not more than 20 nautical miles from a harbor of safe refuge (Office of Federal Register National Archives and Records Administration, 2004).

Protected Waters: are sheltered waters that present no special hazards (Office of Federal Register National Archives and Records Administration, 2004).

Vessel Stability: refers to the tendency of a ship to remain upright or return to upright when inclined by forces that are caused by the action of waves, wind, passenger movement, etc (Office of Federal Register National Archives and Records Administration, 2004).

Water Taxi: is a motorboat that transports passengers for a fare (Water Taxi, 2008).

Appendix C: Classification of Passenger Vessels

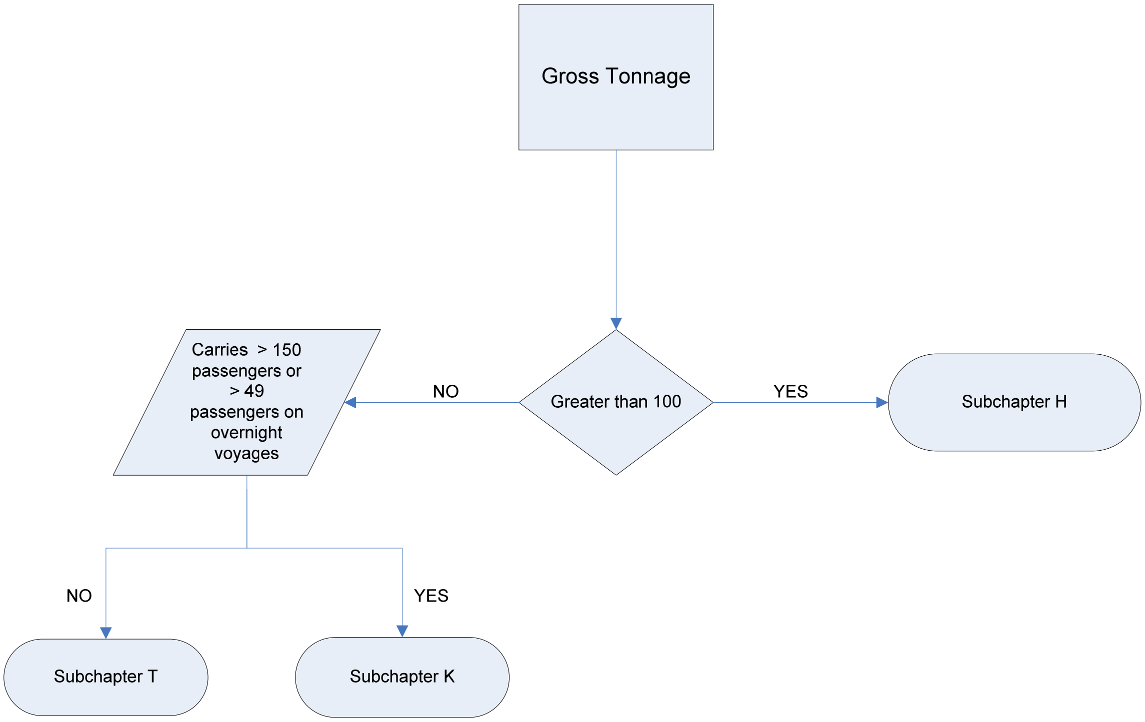


Figure C.1: Passenger Vessel Classification Flow Chart

The Classification of passenger vessels begins with the gross tonnage of the vessel. Once this gross tonnage is established, the number of passengers that the vessel carries is considered. This breakdown will help categorize vessels into subchapters which contain all of the regulations that the vessels must meet (Office of Federal Register National Archives and Records Administration. 2004, Parts 70 to 89, pp. 7-12) .

Appendix D: Proposed Rule Change by the U.S. Coast Guard (excerpt)

49244 Federal Register / Vol. 73, No. 162 /
Wednesday, August 20, 2008 /
Proposed Rules

DEPARTMENT OF HOMELAND SECURITY

Coast Guard

46 CFR Parts 71, 114, 115, 122, 170, 171, 172, 174, 175, 176, 178, 179, and 185

[Docket No. USCG–2007–0030]
RIN 1625–AB20

Passenger Weight and Inspected Vessel Stability Requirements

AGENCY: Coast Guard, DHS.

ACTION: Notice of proposed rulemaking.

SUMMARY: The Coast Guard proposes to amend its regulations governing the stability of passenger vessels and the maximum number of passengers that may safely be permitted on board a vessel. The average American weighs significantly more than the assumed average weight per person utilized in current regulations, and the maximum number of persons permitted on a vessel is determined by several factors, including an assumed average weight for each passenger. Updating regulations to more accurately reflect today's average weight per person will maintain intended safety levels by taking this weight increase into account. The Coast Guard is also taking this opportunity to clarify and update intact stability and subdivision and damage stability regulations.

DATES: Comments and related material must reach the Docket Management Facility on or before November 18, 2008. Comments sent to the Office of Management and Budget (OMB) on collection of information must reach OMB before November 18, 2008.

ADDRESSES: You may submit comments identified by Coast Guard docket number USCG–2007–0030 to the Docket Management Facility at the U.S. Department of Transportation. To avoid duplication, please use only one of the following methods:

(1) *Online: http:// www.regulations.gov.*

(2) *Mail:* Docket Management Facility (M–30), U.S. Department of Transportation, West Building Ground Floor, Room W12–140, 1200 New Jersey Avenue, SE., Washington, DC 20590–0001.

(3) *Hand delivery:* Room W12–140 on the Ground Floor of the West Building, 1200 New Jersey Avenue, SE., Washington, DC 20590, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays. The telephone number is 202–366–9329.

(4) *Fax:* 202–493–2251.

You must also send comments on collection of information to the Office of Information and Regulatory Affairs, Office of Management and Budget. To ensure that the comments are received on time, the preferred method is by email at *oira_submission@omb.eop.gov* or fax at 202–395–6566. The subject line should include the docket number (USCG–2007–0030) and say ATTN: Desk Officer, U.S. Coast Guard, DHS. An alternate, though slower, method is by U.S. mail to the Office of Information and Regulatory Affairs, Office of Management and Budget, 725 17th Street, NW., Washington, DC 20503, *Attn:* Desk Officer, U.S. Coast Guard.

You may inspect the material proposed for incorporation by reference at room 1308, U.S. Coast Guard Headquarters, 2100 Second Street, SW., Washington, DC 20593–0001 between 9 a.m. and 4 p.m., Monday through Friday, except Federal holidays. The telephone number is 202–372–1372. Copies of the material are available as indicated in the ''Incorporation by Reference'' section of this preamble.

FOR FURTHER INFORMATION CONTACT: If you have questions on this proposed rule, call Mr. William Peters, U.S. Coast Guard, Office of Design Engineering Standards, Naval Architecture Division (CG–5212), telephone 202–372–1371. If you have questions on viewing or submitting material to the docket, call Ms. Renee V. Wright, Program Manager, Docket Operations, telephone 202–366–9826.

SUPPLEMENTARY INFORMATION:

Table of Contents for the Preamble

I. Public Participation and Request for Comments

We encourage you to participate in this rulemaking by submitting comments and related materials. All comments received will be posted, without change, to *http://www.regulations.gov* and will include any personal information you have provided. We have an agreement with the Department of Transportation (DOT) to use the Docket Management Facility. Please see DOT's ''Privacy Act'' paragraph below.

A. Submitting Comments

If you submit a comment, please include the docket number for this rulemaking (USCG–2007–0030), indicate the specific section of this document to which each comment applies, and give the reason for each comment. We recommend that you include your name and a mailing address, an e-mail address, or a phone number in the body of your document so that we can contact you if we have questions regarding your submission.

You may submit your comments and material by electronic means, mail, fax, or delivery to the Docket Management Facility at the address under **ADDRESSES**; but please submit your comments and material by only one means. If you submit them by mail or delivery, submit them in an unbound format, no larger than 8½ by 11 inches, suitable for copying and electronic filing. If you submit them by mail and would like to know that they reached the Facility, please enclose a stamped, self-addressed postcard or envelope. We will consider all comments and material received during the comment period. We may change this proposed rule in view of them.

B. Viewing Comments and Documents

To view comments, as well as documents mentioned in this preamble as being available in the docket, go to *http://www.regulations.gov* at any time. Enter the docket number for this rulemaking (USCG–2007–0030) in the Search box and click ''Go >>.'' You may also visit the Docket Management Facility in Room W12–140 on the ground floor of the DOT West Building, 1200 New Jersey Avenue, SE., Washington, DC 20590, between 9 a.m. and 5 p.m., Monday through Friday except Federal holidays.

C. Privacy Act

Anyone can search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review the Department of Transportation's Privacy Act Statement in the **Federal Register** published on April 11, 2000 (65 FR 19477), or you may visit *http://DocketsInfo.dot.gov.*

D. Public Meeting

We do not now plan to hold a public meeting. But you may submit a request for one to the Docket Management Facility at the address under **ADDRESSES** explaining why one would be beneficial. If we determine that one would aid this rulemaking, we will hold one at a time and place announced by a later notice in the **Federal Register**.

E. Technical Review by Society of Naval Architects and Marine Engineers

An *ad hoc* panel of the Society of Naval Architects and Marine Engineers (SNAME) has reviewed reports delivered to the Coast Guard by BMT Designers and Planners and CSC Advanced Marine Center and provided technical advice concerning vessel stability and increased passenger weight. SNAME is a nonprofit, professional society, and the panel's 28 experienced naval architects are able to provide technical peer review from a broad cross-section of the designers, builders and operators of passenger vessels. The Charter for *Ad Hoc* Panel 15 on Loading Criteria for People Aboard Passenger Vessels and a memorandum from the panel's chairman to the Coast Guard concerning the Phase 1 Impact Analysis Report from BMT Designers and Planners are available in the docket at *http://www.regulations.gov.* A list of the panel's members and information about their meetings is available at *http://www.sname.org/committees/tech_ops/O44/passenger/activity-15.html*. The Coast Guard will make any additional reports from the *ad hoc* panel available to the public by posting them to the docket.

II. List of Acronyms

2008 IS Code International Code on Intact Stability, 2008
ABS American Bureau of Shipping
CDC Centers for Disease Control and Prevention
CFR Code of Federal Regulations
COI Certificate of Inspection
DHS Department of Homeland Security
DOT Department of Transportation
FAA Federal Aviation Administration
EO Executive Order
FR Federal Register
GM Metacentric height
LBP Length Between Perpendiculars
LCG Longitudinal Center of Gravity
MARPOL International Convention for the Prevention of Pollution from Ships
MSC Marine Safety Center
NHANES National Health and Nutrition Examination Survey
MISLE Marine Information for Safety and Law Enforcement
NAICS North American Industry Classification System
NEPA National Environmental Policy Act of 1969 NPRM Notice of Proposed Rulemaking NTSB National Transportation Safety Board
OCMI Officer in Charge, Marine Inspection OMB Office of Management and Budget PSSC Passenger Ship Safety Certificate PSST Pontoon Simplified Stability Proof Test SBA United States Small Business Administration
SNAME Society of Naval Architects and Marine Engineers
SOLAS International Convention for the Safety of Life at Sea
SST Simplified Stability Proof Test
U.S.C. United States Code
VCG Vertical Center of Gravity

III. List of Terms

Angle of heel means the angle of the vessel's centerline to the upright when the vessel is inclined.

Deadweight survey: See *lightweight survey.*

Draft means the vertical distance from the bottom of the hull (*i.e.*, the keel) or another point that protrudes below the hull to the waterline.

Exposed waters generally means more than 20 nautical miles from a harbor of safe refuge.

Flush deck means any continuous, unbroken deck from stem to stern.

Freeboard means the vertical distance from the deck edge to the waterline. A decrease in freeboard (i.e. reduced freeboard) corresponds to an increase in draft.

Heel is the degree to which a ship leans transversely as a result of variable and dynamic external forces.

Heeling moment is generally a force acting through a distance that causes a vessel to roll or heel to one side. A heeling moment that is larger than the vessel's righting ability can cause the vessel to overturn or capsize. Coast Guard requirements limit the amount of heel a vessel can have when wind or passenger movement causes the heeling moment. *Inclining or stability test* is a methodical process that involves moving a series of known weights on a vessel and measuring the resulting change in the equilibrium heel angle to determine the vessel's stability characteristics.

Intact stability generally means the stability properties of a vessel without any damage to its watertight buoyancy volume.

Length between perpendiculars (LBP) means the length of the summer load waterline from the vessel's stern post to the point where it crosses the vessel's stem.

Lightship displacement or lightweight means the weight of a vessel that is complete in all respects, but without consumables, stores, cargo, passengers, crew, and their effects, and without any liquids on board except fixed ballast and machinery and piping fluids, such as lubricants and hydraulics, which are at operating levels.

Lightweight survey is a part of the stability test that determines any changes in lightship displacement and longitudinal center of gravity (LCG). It involves taking an audit of all items that should be added, deducted, or relocated on a vessel so that the observed condition of the vessel can be adjusted to the lightship condition. Often referred to as a *deadweight survey.*

*Longitudinal center of gravity (LCG)*means the location along the vessel's length at which the total weight of the vessel may be assumed to act. *Master* means a person holding a valid license that authorizes that person to serve as a master of a passenger vessel.

Open boat means a vessel not protected from entry of water by means of a complete weathertight deck.

Operator means the person or entity who provides operational instructions to and receives reports from the master of the vessel and is responsible for the vessel's maintenance and repair, schedule of operations, crewing, etc.

Owner means the person or entity holding title to the vessel.

Partially protected waters generally means not more than 20 nautical miles from a harbor of safe refuge.

Passenger heel refers to the heeling moment that occurs when passengers move to one side of the vessel's centerline, causing the vessel to roll, or heel.

Pontoon vessel generally means any vessel having two or more sealed hulls, which are structurally independent and detachable from the vessel's deck or cross structure.

Protected waters generally means sheltered waters that present no special hazards.

Sailing vessel means a vessel that is propelled by wind, using sails.

Subdivision and damage stability refers to the stability characteristics of a vessel when damaged, generally focusing on flooding of watertight compartments.

Vertical center of gravity (VCG) means the height above the keel at which the total weight of the vessel may be assumed to act.

Vessel stability refers to the tendency of a ship to remain upright or return to upright when inclined by forces that are caused by the action of waves, wind, passenger movement, etc.

Waterplane means the horizontal area obtained from the intersection of the ship's hull with the water's surface at a particular draft. The waterplane area is used to calculate how much immersion will be caused by additional weight.

Wind heel refers to the heeling moment caused when the wind acts on the lateral area of the vessel above the waterline and causes the vessel to roll, or heel.

IV. Background and Purpose

The total number of persons permitted on a passenger vessel, inspected and certificated under 46 CFR Subchapters H, K or T, is limited by a number of different design factors, one of which is stability. Stability requirements include intact stability for almost all vessels, as well as subdivision and damage stability generally for any vessel carrying more than 49 passengers and all vessels over 65 feet in length. This NPRM is intended to clarify and update both intact stability and subdivision and damage stability regulations, primarily related to the carriage of passengers for hire, and to update the weight per person used for all vessels. The intent of this rulemaking is to ensure that each vessel operates without being overloaded. The overall good safety record of the passenger vessel industry reflects safety factors inherent in the stability requirements applied to passenger vessels. Increasing the passenger weight to reflect current data will help ensure that the safety margins included in our regulations remain valid.

These safety margins operate in two ways. The first is through intact stability, which generally relates to the stability of a vessel in normal operation.

The second is through subdivision and damage stability, which generally relates to the stability of a vessel in an emergency involving a flooded condition.

A vessel's stability information, including any restrictions on route and the number of passengers permitted, is provided to the vessel operator most often in the form of a stability letter issued by the Coast Guard's Marine Safety Center (MSC), and/or a Coast Guard Certificate of Inspection (COI) issued by the Officer in Charge, Marine Inspection (OCMI). When both are provided, restrictions on the COI govern. The COI is issued after the vessel's stability has been evaluated in one of two ways:

For vessels greater than 65 feet in length, stability is evaluated through detailed design calculations—submitted to the MSC—that produce the vessel's stability requirements. This process, which takes into account the assumed total weight of persons on board, is described in 46 CFR, subchapter S, parts 170 and 171.

Vessels not greater than 65 feet in length normally undergo a performance test conducted in the presence of the OCMI, instead of submitting design stability calculations to the MSC (46 CFR part 178). This performance test, which also takes into account the assumed total weight of persons on board, is either a simplified stability proof test (SST) or, if the vessel is a pontoon vessel, a pontoon simplified stability proof test (PSST). The SST is intended to evaluate monohull vessels, and the PSST is intended to evaluate pontoon vessels operating on protected waters. For ease of discussion, we will use the term SST in this preamble to describe any simplified stability proof test.

Vessels to which these tests do not apply may need to be evaluated through design calculations to show that they meet intact stability requirements.

Alternately, a vessel might satisfy stability requirements by complying with a standard acceptable to the Commanding Officer, Marine Safety Center. Finally, simplified subdivision calculations may be necessary for some vessels not greater than 65 feet in length.

To arrive at a total assumed weight of persons on board for calculating stability, an assumed average eight per person is used. Section 178.330 of Title 46 of the CFR specifies that the assumed average weight per person is 160 pounds, except that vessels operating exclusively on protected waters and carrying a mix of men, women, and children may use an average weight of 140 pounds per person. These weights were established in the 1960s.

In a report issued in October 2004, the Centers for Disease Control and Prevention (CDC) concluded that the average weight of an individual in the United States has increased dramatically in the last 40 years, with the greatest increase seen in adults. (The report, *Advance Data From Vital Health Statistics Mean Body Weight, Height,and Body Mass Index, United States 1960–2002,* No. 347, October 27, 2004, is available in the docket.)

This increase in passenger and crew weight can have an adverse effect on the stability of passenger vessels due to several factors, including increased vertical center of gravity, reduced freeboard, and increased passenger heeling moment.

On December 20, 2004, the National Transportation Safety Board (NTSB) issued Safety Recommendation M–04–04 (available in the docket), which included findings that the current 140 pound per person weight allowance for operations on protected waters does not reflect actual loading conditions. The NTSB recommended that the Coast Guard revise its guidance to OCMIs for determining the maximum passenger capacity of small passenger pontoon vessels either by: (1) Dividing the vessel's SST weight by 174 pounds per person; or (2) restricting the actual cumulative weight of passengers and crew to the vessel's SST weight. In correspondence to the NTSB dated April 7, 2005 (available in the docket), the Coast Guard concurred that the average weight per person used in SSTs needed to be updated, and noted that an internal Coast Guard study identified the same issue. That study, which is entitled *Study of Effects on Commercial Passenger Vessels Due to Weight Standards,* is available in the docket. This notice of proposed rulemaking (NPRM) follows notices to the public, published in the **Federal Register** on April 26, 2006 (71 FR 24732) and November 2, 2006 (71 FR 64546), recommending voluntary interim measures for passenger vessels to follow while the Coast Guard studied the issue of increased passenger weight. In summary, those voluntary measures advised pontoon vessels and other small passenger vessels to (1) more stringently monitor wind and wave conditions prior to departure and (2) begin using 185 pounds as the new assumed average weight per person when calculating passenger capacity. A discussion of how 185 pounds was chosen is contained in the April 26, 2006 notice and in the discussion of § 170.090 in this preamble. At last count, the Docket Management Facility received 108 comments from the public in response to those notices. They are posted for public view at *http://www.regulations.gov* under docket number USCG–2007–0030, and can be viewed by following the directions in the ‘‘Viewing comments and documents’’ section of this preamble. We will respond to those comments, together with comments received in response to this NPRM, when we publish an effective rule. Finally, this proposed rule is an opportunity to identify where corrections, clarifications, and updates need to be made to existing regulations. These proposed changes, which would include changes in international requirements, will be discussed in greater detail later in this preamble, under ‘‘Corrections, Clarifications, and Updates.’’

V. Discussion of Proposed Rule

For easier reference, we have divided this discussion into the following topics: A. Vessel stability; B. Weight of Passengers and Crew; C. Notes on Pontoon Vessels; D. SOLAS and Resolution A.265; E. Corrections, Clarifications, and Updates; F. American Bureau of Shipping; and G. Discussion of Proposed Amendments by Section.

A. Vessel Stability

An increase in passenger and crew weight will typically have an adverse effect on vessel stability. Whether or not such additional weight would result in non-compliance of a vessel with applicable stability criteria depends upon the amount and location of the additional weight, the degree by which the vessel demonstrated compliance with the stability criteria previously, and which of the criteria was limiting, if any. Historically, a margin of safety has been built into the requirements for both intact stability and subdivision and damage stability. The standards for intact stability criteria are generally designed to provide vessels with adequate ability to resist overturning heeling moments, such as those caused by wind or passenger weight shifting to one side. Standards for subdivision and damage stability are designed to address the worst case loading conditions and certain flooding scenarios that could occur as a result of accidental damage.

Although intact stability and subdivision and damage stability standards address different stability risks, we believe that these two stability standards together are responsible in part for the good safety record of the passenger vessel industry. Therefore, we are proposing that intact stability and subdivision and damage stability requirements utilize an updated assumed average weight per person. We also propose adding more specific requirements for a vessel owner or operator to show that the vessel meets intact stability and subdivision and damage stability standards, including provisions accounting for possible changes in vessel and weight per person. These requirements will improve a master’s ability to meet stability criteria for the intended service and also avoid overloading the vessel.

Additionally, to help ensure that vessels maintain the intended safety levels after initial certification, we would clarify the requirement that stability information be checked at each annual inspection or COI renewal to confirm that it is still valid for the loading and service intended.

Finally, we propose requiring stability verification—including calculations—at least every ten years.

We propose detailing these requirements in new sections that would be added to each of the three subchapters that address the inspection of passenger vessels. The new sections, entitled ‘‘Stability Verification,’’ would be added at § 71.25–50 in subchapter H, § 115.505 in subchapter K, and § 176.505 in subchapter T (all of which are contained in chapter I, Title 46 of the CFR). Each new section would be comprised of paragraphs (a), (b), (c) and (d).

So that owners, operators, and OCMIs may clearly understand these requirements, how we intend to implement them, and the analyses upon which they are based, a discussion in three parts is given below:

‘‘Part One—Explanation’’ describes the purpose and intent behind each of the paragraphs—(a), (b), (c), and (d)—in the proposed new ‘‘Stability Verification’’ sections. ‘‘Part Two—Analysis’’ describes the process whereby the Coast Guard developed an assessment methodology for prioritizing the vessels that would require stability verification.

‘‘Part Three—Assessment Methodology’’ describes the methodology to be used by owners, operators, and OCMIs to, first, determine whether a change in the permitted number or distribution of passengers might be necessary and, second, to assess whether a vessel would be likely to require new stability testing or evaluation.

Part One—Explanation

Paragraph (a) of §§ 71.25–50, 115.505,
and 176.505 Paragraph (a) would add, as the owner or operator’s responsibility, two checks regarding the vessel’s stability information. First, at each annual inspection and Certificate of Inspection (COI) renewal, the owner or operator would demonstrate that the stability information is still appropriate for the vessel’s intended loading and service.

This requirement would augment the confirmation by a Coast Guard marine inspector that a valid stability letter is properly posted aboard a vessel.

Second, the owner or operator would need to confirm that the total weight of gear and variable loads is still valid for the intended service. (The total weight of gear and variable loads, including the total weight of persons carried, is the basis for the stability letter and/or the COI.) The owner or operator would need to ensure that the master knows both the maximum total weight of persons and the average weight per person on which the total weight is based. Currently, all passenger vessels are required to comply with a section in the ‘‘Operations’’ part of each inspection subchapter (§§ 78.17–22, 122.315, and 185.315 of this title) that requires a master to verify, prior to departure on every voyage, that the loaded vessel complies with all stability information, and that the stability information is being used properly to ensure that the vessel is not overloaded. Paragraph (a) would add a requirement that the owner or operator demonstrate the methods the master uses to do this. Such methods could include the competent reading of loading or draft marks, and must include the proper use of that information for complying with the draft and/or freeboard restrictions normally contained in the stability letters for these types of vessels. If the stability information is no longer valid, a new stability letter would be needed. The new stability letter would contain revised operating restrictions that the master should follow to avoid overloading the vessel and to maintain compliance with stability requirements. The following flowchart illustrates the stability confirmation process discussed above:

Paragraph (b) of §§ 71.25–50, 115.505, and 176.505. This paragraph would require a vessel’s stability to be verified at 10 year intervals or when modifications are made to the vessel that could affect the vessel’s ability to meet stability requirements. The 10 year ‘‘clock’’ would start whenever the last stability verification was conducted or stability letter was issued, or when a determination of sister vessel status was made (as permitted in part 170 of Subchapter S). The ‘‘clock’’ would be reset after each stability verification. For a vessel that would be issued a SOLAS Passenger Ship Safety Certificate (PSSC), the SOLAS requirement for a lightweight survey to be conducted at least once every 5 years would constitute a verification of the vessel's stability for the purposes of this paragraph. In other words, paragraph (a) requires the owner or operator to make sure that the vessel master knows what the vessels' stability limits are, based on the most recent stability calculations.

Paragraph (b) requires new calculations of the per-person weight, and then requires the use of that weight to verify—usually with calculations—that the vessel still meets applicable stability requirements.

Paragraph (c) of §§ 71.25–50, 115.505, and 176.505.

This paragraph would provide the minimum requirements for what the stability verification required by paragraph (b) would include. The requirements would vary depending on whether the vessel's stability compliance was governed by subchapter S or subchapter T of title 46 CFR.

Subchapter S requires that detailed design calculations be submitted to the Marine Safety Center (MSC), as described in parts 170 and 171. This requirement also applies to all subchapter H and K vessels and some subchapter T vessels. However, a simplified test, either an SST or PSST, is performed for most subchapter T vessels, as described in part 178. In cases where a simplified test is neither feasible nor appropriate, a stability standard would be determined by the MSC.

Unless the OCMI permits the use of another value, the assumed average weight per person would be determined according to proposed paragraph 170.090(d) or 178.330(a)(4)(ii), whichever is applicable. The OCMI may permit another value when the owner or operator can show that another value more accurately represents the average weight of persons carried in service; for example when the vessel carries primarily children.

Using a total weight of persons based on this latest average weight per person (i.e., the new total test weight), the owner or operator would need to verify that the vessel meets applicable stability criteria.

For subchapter S compliance, this would mean that calculations would need to be performed if the total weight of persons carried is greater than the total weight used in the previous stability verification.

For vessels undergoing a simplified proof test, the owner or operator would need to either perform a new test using the new total test weight, or prove that the vessel could meet current applicable requirements using data from the most recently performed simplified test, if those data are valid.

For vessels meeting subchapter S requirements, the verification would also include conducting a deadweight survey to verify that the vessel's stability characteristics have not changed significantly, and that it remains in compliance with applicable stability criteria. (Coast Guard policy for what constitutes a significant change is contained in Marine Safety Center Technical Note (MTN) 04–95, *Lightship Change Determination; Weight-Moment Calculation* vs. *Deadweight Survey* vs. *Full Stability Test,* available in the docket.) If sufficient accuracy can be obtained for the stability verification prior to the deadweight survey, some relaxation in the deadweight survey requirements could be accepted by the MSC. For example, a greater number of tanks containing operating liquids could be kept at normal levels. If the lightship characteristics have changed so that stability compliance is not assured under the existing stability information, a new stability analysis— together with associated loading calculations—would be needed, and a new stability letter would be issued.

When the passenger capacity of a vessel is limited by subdivision and/or damage stability considerations, the proposed increase in assumed average passenger weight may require a corresponding reduction in passenger capacity. For example, in a passenger vessel to which 46 CFR 179.220 is applicable, an increase in the assumed average weight per person could cause either a change in freeboard, resulting in a reduction in the permissible distance between watertight bulkheads (see 46 CFR 179.220(a)(2)), or a reduction in the permitted number of passengers in order to remain in compliance with existing subdivision and damage stability requirements. In a vessel to which subchapter S subdivision and damage stability requirements are applicable, increased passenger weight could cause the margin line to become submerged in the flooded condition, which regulations prohibit. Owners of such vessels as those discussed above may seek to modify their vessels to maintain their current passenger count. When significant, such modifications may be determined by the Coast Guard to be ‘‘major conversions.’’

When a modification constitutes a major conversion, it is appropriate to bring the vessel into compliance with the latest safety standards where it is both reasonable and practicable to do so. The cognizant OCMI makes a determination on which areas of a vessel undergoing major conversion must be brought into compliance.

In all cases, for a passenger vessel that undergoes a major conversion or incurs changes that affect its stability, the required verification of both intact stability and subdivision and damage stability compliance would use the latest assumed average weight per person.

Paragraph (d) of §§ 71.25–50, 115.505, and 176.505.

This paragraph would permit the Coast Guard authority responsible for issuing the stability information to defer or dispense with stability verification based on the vessel's characteristics or the degree to which the vessel could be affected by increased weight per person or vessel weight. For vessels that are subject to subchapter S requirements, this authority is normally the Commanding Officer, Marine Safety Center; for vessels whose stability is based on a simplified stability test, this authority is normally the OCMI. Analyses described under the ensuing ‘‘Part Two—Verification Process’’ of this preamble showed that some vessel types experience a negligible effect from increased passenger weight. These vessel types include sailing vessels, vessels that carry substantial cargo amounts compared to the passenger weight, vessels that have an established process to avoid overloading, and/or vessels that follow the voluntary measures for prudent operation contained in the **Federal Register** notice published on April 26, 2006 (71 FR 24732). A more detailed description of those vessels relatively unaffected by an increase in weight per person can be found in ‘‘Part Three—Assessment Methodology.’’

Part Two—Analysis

The Coast Guard sponsored an analysis of the impact of increased weight per person on the U.S. inspected passenger vessel fleet. From the Marine Information for Safety and Law Enforcement (MISLE) database, we found that nearly 75 percent of the inspected U.S. flag passenger vessels are 65 feet in length or less. The stability of most of these vessels was based on the performance of a simplified stability test (SST), either for a monohull or a pontoon passenger vessel.

The analysis showed that the effect of increased passenger weight on vessels depended on factors not included in the MISLE database, such as the amount of freeboard and draft and whether the vessel is a flush deck or open boat type.

To supplement that study, additional stability analyses were performed on a number of monohull vessels that had undergone SSTs. By analyzing the SST results, conservative estimates of key parameters—such as the moment to heel 1 degree—can be made, that, in turn, can be used in an assessment methodology for intact stability verification.

These analyses were peer-reviewed by the Society of Naval Architects and Marine Engineers (SNAME) *Ad Hoc* Panel No. 15, which provided both a technical appraisal of the analyses and recommendations on how they could be used. Two of the panel’s recommendations are associated with the proposed prioritizing process: (1) The panel recommended the Coast Guard adopt a risk-based process that looks at relative changes to a vessel’s stability characteristics and compares these relative changes to acceptable limits determined by the Coast Guard; and (2) The panel recommended the Coast Guard adopt a technical process in reviewing stability. That process would use the stability requirements the vessel is designed to meet to determine if the vessel has been adversely affected by an increase in passenger weight such that a new stability evaluation should be performed. We agree with these recommendations. In addition, based on the analyses of the impact of increased passenger weight on the passenger vessel fleet, we developed an assessment methodology, detailed in ‘‘Part Three—Assessment Methodology’’ below, that reflects these recommendations.

As stated above, this proposed rule would require that a stability verification be performed within ten years of the date the last stability letter was issued or a previous stability verification was performed. Regardless of when the stability information was issued, however, all vessels must meet stability requirements using the latest assumed average weight per person immediately upon the effective date of this rule. Additionally, in all cases, when a vessel or its loading is modified in any way that alters its stability, a stability verification is required as soon as is practicable, using the latest assumed average weight per person.

Since a very large portion of inspected passenger vessels currently have stability letters that are more than 10 years old, we developed a process that allows owners, operators, and OCMIs to determine whether the stability verification should be conducted as soon as is practicable, deferred to a later date—most likely the next regular inspection—or perhaps dispensed with.

This process would more evenly distribute demand for the Coast Guard resources that will be necessary to guide implementation of this proposed rule.

The following flowchart illustrates the prioritizing process, discussed in detail below.

Three—Assessment Methodology

The process by which an owner, operator, or OCMI would determine whether a vessel would need to reduce or redistribute passengers and whether it would need a new stability verification—and how soon—is laid out in detail below: First for vessels subject to the requirements of subchapter S, and second for vessels that undergo a simplified proof test.

However, there are several vessel categories for which no further assessment of passenger weight needs to be considered, with the exception that a new stability letter might be required. No immediate stability verification or change to passenger capacity is necessary if the vessel:

1. Is a sailing vessel;
2. Has a Certificate of Inspection (COI)
that permits 86 percent (approximately equal to 160 pounds divided by 185 pounds) or fewer of the passengers permitted by the stability letter, and the assumed weight per person was 160 or 165 pounds;
3. Has a COI that permits 75 percent (approximately equal to 140 pounds divided by 185 pounds) or fewer of the passengers permitted by the stability letter, if operating on protected waters with a mix of men, women, and children, and the assumed weight per person was 140 pounds;
4. Is permitted to carry an amount of cargo, not including passengers, that exceeds the total weight of passengers carried; or
5. Ensures that the total weight of persons aboard the vessel does not exceed the assumed total weight of persons used to develop the stability

information, which is equal to the total test weight.

Assessment of vessels subject to the requirements of subchapter S.

The SNAME *Ad Hoc* panel also proposed, and the Coast Guard, in turn, proposes a process for evaluating stability change in these vessels using the latest assumed average weight per person. By following the process below, the owner, operator, or OCMI could determine the urgency of each vessel's need for a re-evaluation of intact stability and prioritize the vessel accordingly. The data necessary for making the percent change and detailed loading calculations described below should be readily available, as § 78.17– 22(b) requires that vessel masters have the capability to determine the vessel's draft, trim, and stability as necessary.

Evaluation process for a vessel subject to the requirements of subchapter S.

The following three assumptions were applied:

1. Wind heel requirements are more severe than passenger heel, and this doesn't change with an increase in weight per person. Experience has shown that passenger heel requirements in subchapter S rarely exceed wind heel requirements.
2. Each vessel meets stability requirements in its current condition, prior to assessing the effect of a perperson weight increase. Our assessment cannot take into account unauthorized changes to the vessel or its service.
3. A small amount of increase in weight or vertical center of gravity (VCG) will not adversely affect the stability of the vessel significantly. This approach is taken from MTN 4– 95 (available in the docket), which uses weight-moment calculations to assess the absolute and relative changes in displacement and centers of gravity (LCG and VCG). Those changes, in turn, can be compared to previously determined limits to evaluate the relative risk of adverse changes to the vessel's stability. To do this, a calculation is needed that relates the change in vertical weight moment caused by an increase in assumed weight per person ($VMOM_{chng}$) to the lightship vertical weight moment ($VMOM_{lightship}$):

Percent Change = $VMOM_{chng}$/ $VMOM_{lightship}$ · 100

Where:

$VMOM_{chng}$ = (W_{paxnew} ¥ W_{paxold}) · (VCG_{pax})

$VMOM_{lightship}$ = lightship weight · lightship VCG

VCG = vertical center of gravity above baseline

W_{paxnew} = the number of passengers multiplied by the latest assumed average weight per person

W_{paxold} = the number of passengers multiplied by the old assumed average weight per person (generally, either 160 or 165 pounds)

VCG_{pax} = the overall VCG of the passengers carried above the baseline

In making the calculations, consistent units must be used. In other words, if the lightship weight is given in long tons, W_{paxnew} and W_{paxold} must be computed in long tons; if the lightship VCG is in feet, VCG_{pax} must be in feet; if in meters, use meters. MTN 4–95 allows up to a 2 percent change in lightship weight without verifying weight-moment calculations.

Additionally, an OCMI may consider the difference in VCG of the vessel and the passengers. It should be noted that a percent change of the vertical moment of less than 3 provides a value of safety corresponding to the 2 ercent displacement allowed in MTN 4–95. For these reasons, if the percent change in vertical moment computed by the methodology given above is less than 3, an OCMI could defer the stability verification to a later date, most likely the next regularly scheduled inspection.

If the percent change is 3 or greater, and the vessel's most recent stability letter is more than 10 years old, detailed stability calculations should be performed to determine the degree to which, if any, an increase in total assumed passenger weight would affect the vessel's compliance with the applicable stability criteria.

Evaluation process for a vessel undergoing a monohull simplified stability proof test.

This process uses data obtained from the SST data form and the standards given in 46 CFR 178.330. If the data for the SST is not available, vessel measurements will be necessary to obtain the SST data or the moment to heel 1 degree ($MH1_{SST}$) must be estimated as described in the steps below:

1. Using the following equation, calculate the additional sinkage in inches (centimeters) due to the increased passenger weight:

Sinkage = (W_{paxnew} ¥ W_{paxold})/$W_{immersion}$

Where:

$W_{immersion}$ = (Waterplane Area · Water Density/K) in pounds per inch (kilograms per centimeter) (this is the weight per unit immersion); K = 12 inches per foot (100 centimeters per meter)

W_{paxnew} = the number of passengers multiplied by the latest assumed average weight per person in pounds (kilograms)

W_{paxold} = the number of passengers multiplied by the old assumed average weight per person used in the SST (generally, either 140 or 160 pounds) in pounds (kilograms)

Waterplane Area = Length · Beam · Waterplane Coefficient in square feet (square meters)

Waterplane Coefficient = 0.7 for monohulls or 0.4 for multihulls, unless a more accurate value is known

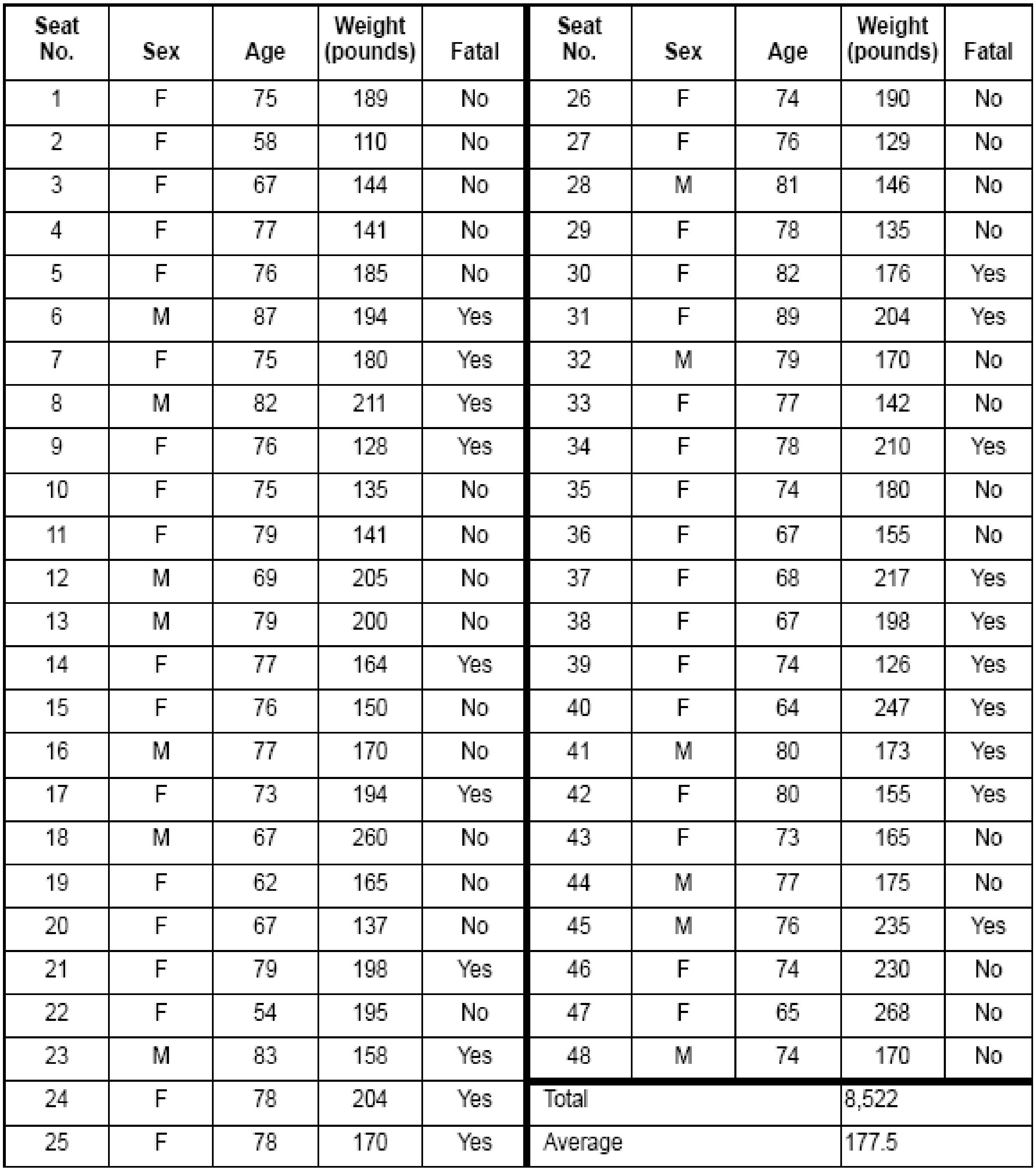
Water Density = 64 pounds per cubic foot (1,025 kilograms per cubic meter) for salt water; 62.4 pounds per cubic foot (1,000 kilograms per cubic meter) for fresh water

2. Calculate the location of the new maximum allowable immersion mark ($i_{upright-new}$) above the upright load waterline by subtracting the sinkage calculated in step 1 above from the SST measured freeboard and applying the appropriate formula from 46 CFR 178.330(d). If the data for an SST is not available, the freeboard should be measured with the vessel in the condition specified in 46 CFR 178.330(a). (In summary, this is with the vessel complete in all respects, in a fully loaded condition, and with all anticipated loads properly distributed.)

(U.S. Coast Guard, 2008)

Appendix E: *Ethan Allen* Individual Passenger Information

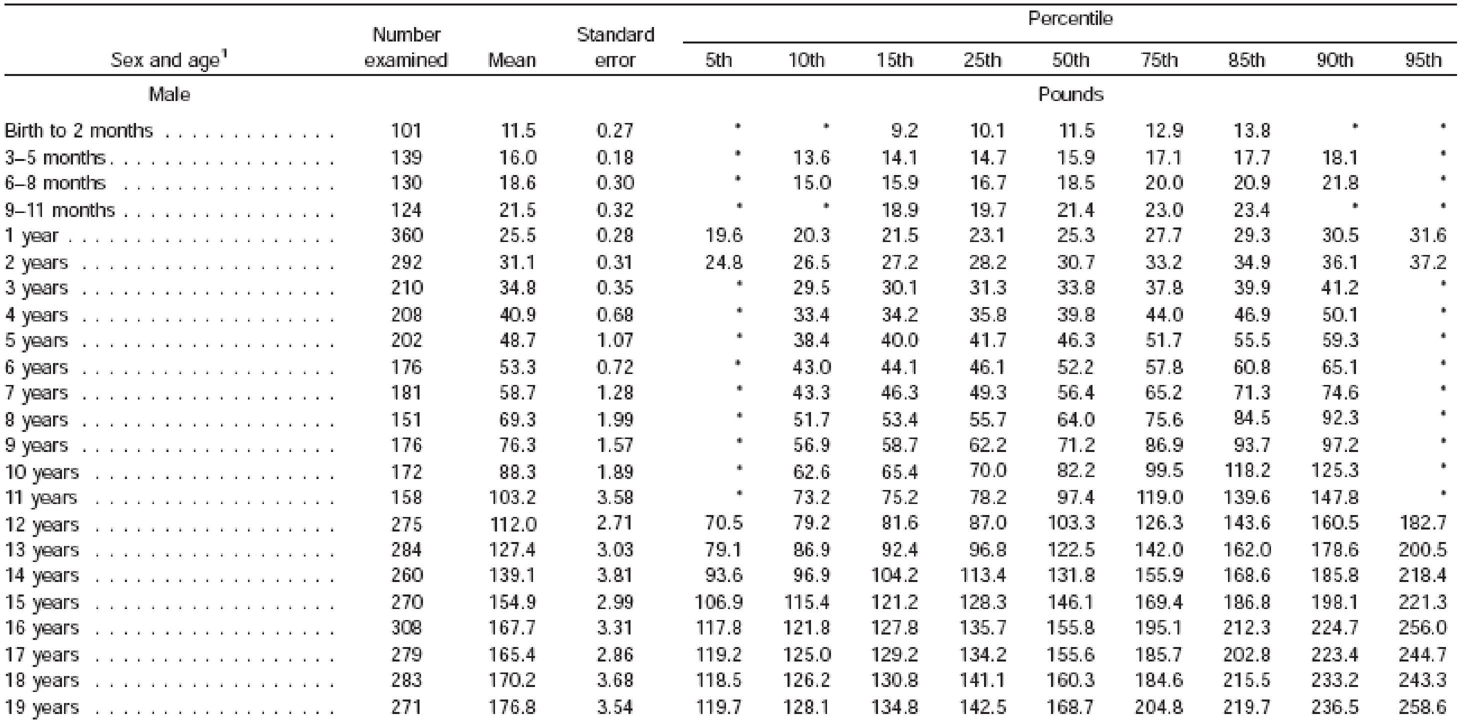
Table E.1: *Ethan Allen* Individual Passenger Information (National Transportation Safety Board, 2006a, p.62)



Seat No.	Sex	Age	Weight (pounds)	Fatal	Seat No.	Sex	Age	Weight (pounds)	Fatal
1	F	75	189	No	26	F	74	190	No
2	F	58	110	No	27	F	76	129	No
3	F	67	144	No	28	M	81	146	No
4	F	77	141	No	29	F	78	135	No
5	F	76	185	No	30	F	82	176	Yes
6	M	87	194	Yes	31	F	89	204	Yes
7	F	75	180	Yes	32	M	79	170	No
8	M	82	211	Yes	33	F	77	142	No
9	F	76	128	Yes	34	F	78	210	Yes
10	F	75	135	No	35	F	74	180	No
11	F	79	141	No	36	F	67	155	No
12	M	69	205	No	37	F	68	217	Yes
13	M	79	200	No	38	F	67	198	Yes
14	F	77	164	Yes	39	F	74	126	Yes
15	F	76	150	No	40	F	64	247	Yes
16	M	77	170	No	41	M	80	173	Yes
17	F	73	194	Yes	42	F	80	155	Yes
18	M	67	260	No	43	F	73	165	No
19	F	62	165	No	44	M	77	175	No
20	F	67	137	No	45	M	76	235	Yes
21	F	79	198	Yes	46	F	74	230	No
22	F	54	195	No	47	F	65	268	No
23	M	83	158	Yes	48	M	74	170	No
24	F	78	204	Yes	Total			8,522	
25	F	78	170	Yes	Average			177.5	

Appendix F: National Health Statistics Report Data Tables

Table F.1a: Weight in pounds for Children and Adolescents from birth through 19 years of age by sex and age, by mean, standard error of the mean, and selected percentiles: United States 2003-2006



				Percentile								
Sex and age[1]	Number examined	Mean	Standard error	5th	10th	15th	25th	50th	75th	85th	90th	95th
Male								Pounds				
Birth to 2 months	101	11.5	0.27	*	*	9.2	10.1	11.5	12.9	13.8	*	*
3–5 months	139	16.0	0.18	*	13.6	14.1	14.7	15.9	17.1	17.7	18.1	*
6–8 months	130	18.6	0.30	*	15.0	15.9	16.7	18.5	20.0	20.9	21.8	*
9–11 months	124	21.5	0.32	*	*	18.9	19.7	21.4	23.0	23.4	*	*
1 year	360	25.5	0.28	19.6	20.3	21.5	23.1	25.3	27.7	29.3	30.5	31.6
2 years	292	31.1	0.31	24.8	26.5	27.2	28.2	30.7	33.2	34.9	36.1	37.2
3 years	210	34.8	0.35	*	29.5	30.1	31.3	33.8	37.8	39.9	41.2	*
4 years	208	40.9	0.68	*	33.4	34.2	35.8	39.8	44.0	46.9	50.1	*
5 years	202	48.7	1.07	*	38.4	40.0	41.7	46.3	51.7	55.5	59.3	*
6 years	176	53.3	0.72	*	43.0	44.1	46.1	52.2	57.8	60.8	65.1	*
7 years	181	58.7	1.28	*	43.3	46.3	49.3	56.4	65.2	71.3	74.6	*
8 years	151	69.3	1.99	*	51.7	53.4	55.7	64.0	75.6	84.5	92.3	*
9 years	176	76.3	1.57	*	56.9	58.7	62.2	71.2	86.9	93.7	97.2	*
10 years	172	88.3	1.89	*	62.6	65.4	70.0	82.2	99.5	118.2	125.3	*
11 years	158	103.2	3.58	*	73.2	75.2	78.2	97.4	119.0	139.6	147.8	*
12 years	275	112.0	2.71	70.5	79.2	81.6	87.0	103.3	126.3	143.6	160.5	182.7
13 years	284	127.4	3.03	79.1	86.9	92.4	96.8	122.5	142.0	162.0	178.6	200.5
14 years	260	139.1	3.81	93.6	96.9	104.2	113.4	131.8	155.9	168.6	185.8	218.4
15 years	270	154.9	2.99	106.9	115.4	121.2	128.3	146.1	169.4	186.8	198.1	221.3
16 years	308	167.7	3.31	117.8	121.8	127.8	135.7	155.8	195.1	212.3	224.7	256.0
17 years	279	165.4	2.86	119.2	125.0	129.2	134.2	155.6	185.7	202.8	223.4	244.7
18 years	283	170.2	3.68	118.5	126.2	130.8	141.1	160.3	184.6	215.5	233.2	243.3
19 years	271	176.8	3.54	119.7	128.1	134.8	142.5	168.7	204.8	219.7	236.5	258.6

Table F.1b: Weight in pounds for Children and Adolescents from birth through 19 years of age by sex and age, by mean, standard error of the mean, and selected percentiles: United States 2003-2006

Female												
Birth to 2 months	81	10.9	0.22	*	*	*	9.7	10.8	11.8	*	*	*
3–5 months	94	14.9	0.23	*	*	*	13.7	14.5	16.2	*	*	*
6–8 months	122	17.9	0.30	*	*	15.7	16.1	17.7	19.4	20.2	*	*
9–11 months	126	20.2	0.25	*	*	17.5	18.1	19.9	22.1	22.7	*	*
1 year	328	24.1	0.24	18.4	19.3	20.0	21.7	24.1	26.3	27.5	28.6	29.5
2 years	335	29.5	0.29	22.4	23.7	24.6	26.6	29.0	31.8	34.0	35.4	37.0
3 years	191	34.8	0.45	*	28.2	29.5	31.2	34.2	37.0	39.3	40.8	*
4 years	226	39.4	0.46	*	32.6	33.5	35.4	38.6	42.7	44.6	45.8	*
5 years	199	45.3	0.82	*	35.1	37.2	38.7	43.3	48.7	53.8	56.1	*
6 years	193	51.5	1.08	*	40.6	42.1	43.8	48.8	55.8	60.4	65.5	*
7 years	157	60.2	1.37	*	46.5	47.9	52.7	56.6	65.5	74.1	78.3	*
8 years	184	67.7	2.07	*	49.3	51.8	55.1	62.1	74.8	86.3	92.8	*
9 years	185	81.0	2.18	*	57.9	61.3	65.3	75.0	92.7	102.8	111.8	*
10 years	189	93.5	2.35	*	64.1	67.7	71.6	89.2	108.1	122.4	129.1	*
11 years	175	108.4	2.88	*	73.3	76.7	83.7	104.3	125.1	137.6	150.3	*
12 years	249	116.7	2.88	*	80.2	89.0	96.0	109.1	131.7	148.5	168.0	*
13 years	292	126.4	2.15	81.2	90.9	94.7	103.9	119.9	139.8	160.0	167.6	195.2
14 years	269	129.6	3.85	*	97.1	101.1	106.8	120.0	142.9	167.2	178.6	*
15 years	248	134.2	1.67	*	102.4	104.9	111.7	126.9	149.0	169.0	178.5	*
16 years	253	135.6	2.10	*	104.2	109.1	117.3	129.7	147.7	157.7	175.5	*
17 years	252	145.6	3.65	*	108.1	113.3	119.4	133.6	158.5	175.6	192.5	*
18 years	272	149.0	4.75	*	105.3	109.6	120.3	138.8	168.1	190.0	203.0	*
19 years	239	148.6	3.95	*	112.2	116.4	121.9	138.9	162.2	185.8	204.3	*

Table F.2: Weight in pounds for females 20 years of age and older by race and ethnicity and age, by mean, and standard error of the mean, and selected percentiles: United States, 2003-2006

Race and ethnicity and age	Number examined	Mean	Standard error	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All race and ethnicity groups[1]								Pounds				
20 years and over	4,330	164.7	1.17	111.2	118.0	123.8	132.8	155.8	185.9	207.5	224.3	250.4
20–29 years	706	155.9	2.27	105.8	113.1	117.0	124.1	144.0	173.7	195.5	217.4	244.2
30–39 years	663	164.7	2.34	112.8	119.3	124.5	131.9	154.8	184.3	208.0	224.3	251.8
40–49 years	779	171.3	2.27	115.3	121.8	128.2	138.4	160.8	196.6	220.7	235.0	257.7
50–59 years	602	172.1	2.53	114.1	120.7	126.7	138.7	162.5	194.2	219.1	234.3	259.7
60–69 years	694	170.5	2.02	114.3	125.1	130.6	141.1	163.1	191.6	212.6	224.9	248.8
70–79 years	468	155.6	2.35	109.0	117.3	121.4	132.2	150.6	174.0	185.3	201.0	218.0
80 years and over	418	142.2	1.53	101.7	109.9	115.3	121.8	140.6	158.5	169.0	177.7	190.5
Non-Hispanic white												
20 years and over	2,233	163.7	1.26	112.1	118.5	124.3	133.0	154.5	183.9	204.2	221.9	246.0
20–39 years	615	158.9	2.17	111.2	116.1	120.4	128.1	148.0	177.9	198.8	217.1	244.0
40–59 years	674	171.0	2.01	115.2	122.1	127.5	138.5	160.7	194.6	215.3	233.8	257.0
60 years and over	944	158.8	1.32	108.3	118.0	122.9	133.6	154.2	178.0	191.8	205.2	225.1
Non-Hispanic black												
20 years and over	959	184.8	1.56	116.9	127.6	135.3	151.2	176.8	209.6	233.3	252.2	275.9
20–39 years	329	181.6	2.94	115.8	124.3	131.7	146.8	171.0	207.9	229.2	249.6	274.0
40–59 years	355	190.1	1.61	120.2	133.4	146.5	159.2	180.9	214.2	238.4	259.7	278.7
60 years and over	275	180.8	2.94	116.3	123.7	131.1	145.7	174.2	207.0	224.4	238.9	261.8
Mexican American												
20 years and over	817	162.2	2.07	111.4	118.6	124.1	133.7	156.0	183.1	200.2	213.6	229.1
20–39 years	300	160.5	2.73	109.8	116.9	120.6	131.4	155.2	182.7	198.4	210.9	229.2
40–59 years	234	168.4	2.68	118.4	124.6	130.2	139.9	161.9	188.4	207.3	219.7	235.7
60 years and over	283	153.0	2.22	109.8	115.6	121.6	129.9	148.6	171.7	185.3	196.2	216.8

Table F.3: Weight in pounds for males 20 years of age and older by race and ethnicity and age, by mean, standard error of the mean, and selected percentiles: United States 2003-2006

				Percentile								
Race and ethnicity and age	Number examined	Mean	Standard error	5th	10th	15th	25th	50th	75th	85th	90th	95th
All race and ethnicity groups[1]								Pounds				
20 years and over	4,489	194.7	1.02	137.1	147.0	154.6	165.7	188.8	216.8	234.5	245.8	270.3
20–29 years	811	188.3	2.33	132.0	139.7	146.5	157.3	178.7	207.9	230.5	245.8	270.3
30–39 years	741	194.1	1.77	137.9	148.0	154.2	163.8	189.3	216.3	230.0	241.6	266.4
40–49 years	769	202.3	1.83	145.4	156.7	163.3	174.8	196.1	223.1	242.0	251.2	275.0
50–59 years	591	198.8	2.10	142.2	152.2	159.9	169.8	195.5	221.6	238.1	249.4	274.3
60–69 years	669	198.3	2.16	140.7	151.1	158.7	171.2	194.1	220.8	238.1	248.9	267.4
70–79 years	555	187.4	2.03	135.4	144.2	150.7	161.8	184.7	208.8	218.0	230.4	257.4
80 years and over	353	168.1	1.36	122.1	131.5	139.8	147.6	166.5	186.7	197.0	204.9	219.9
Non-Hispanic white												
20 years and over	2,339	197.4	1.05	141.6	151.3	158.0	169.2	192.5	218.6	236.0	246.7	270.5
20–39 years	666	193.5	1.98	138.1	146.6	154.1	164.5	185.7	213.7	230.2	242.0	269.4
40–59 years	709	203.8	1.88	147.5	158.9	165.5	176.0	199.6	226.2	243.0	252.7	273.5
60 years and over	964	192.3	1.27	137.5	147.1	154.0	166.4	188.3	212.5	229.1	242.1	261.6
Non-Hispanic black												
20 years and over	941	199.8	2.19	137.3	146.8	154.7	165.3	190.1	221.5	241.7	259.6	302.5
20–39 years	361	202.4	3.31	136.8	146.8	155.2	164.0	190.0	226.4	247.2	269.6	315.5
40–59 years	316	201.0	2.56	139.7	150.3	155.3	167.4	191.1	221.7	237.3	261.3	303.2
60 years and over	264	189.0	2.66	131.3	141.1	148.4	159.3	186.1	213.7	231.8	240.9	257.2
Mexican American												
20 years and over	903	180.5	1.88	132.3	138.2	145.5	155.5	175.5	198.3	215.4	225.1	248.8
20–39 years	375	181.1	2.89	131.9	136.0	142.9	152.7	174.1	200.9	219.5	227.5	251.9
40–59 years	247	180.7	2.03	134.9	144.5	151.0	159.6	177.7	196.3	206.2	214.9	240.9
60 years and over	281	175.9	2.55	122.6	134.9	143.2	151.3	173.2	196.7	209.8	219.1	236.2

Table F.4: Height in inches for children and adolescents aged 2-19 years by sex and age, by mean, standard error of the mean, and selected percentiles: United States, 2003-2006

Sex and age[1]	Number examined	Mean	Standard error	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
Male								Inches				
2 years	258	36.2	0.09	*	34.2	34.7	35.1	36.2	37.2	37.9	38.1	*
3 years	209	38.8	0.17	*	36.5	36.7	37.4	38.7	40.2	40.9	41.4	*
4 years	206	42.2	0.17	*	39.3	40.1	41.1	42.1	43.6	44.0	44.8	*
5 years	202	45.0	0.20	*	42.1	42.7	43.9	45.1	46.4	47.1	47.6	*
6 years	176	47.5	0.19	*	44.9	45.5	46.3	47.6	48.8	49.4	50.0	*
7 years	181	49.1	0.29	*	44.7	45.5	47.3	49.3	50.9	51.8	52.4	*
8 years	152	51.6	0.27	*	48.7	49.0	50.0	51.3	53.0	54.3	54.8	*
9 years	176	53.9	0.19	*	50.9	51.3	52.3	54.0	55.7	56.4	56.6	*
10 years	171	56.0	0.30	*	52.4	52.9	53.9	55.7	57.9	58.8	59.6	*
11 years	158	59.1	0.46	*	55.4	55.7	56.8	58.8	61.4	62.9	63.4	*
12 years	275	60.9	0.21	*	57.2	57.7	58.9	60.6	63.1	64.0	64.9	*
13 years	284	63.7	0.34	*	58.9	59.7	60.7	63.9	66.3	67.4	68.3	*
14 years	260	66.4	0.28	*	62.3	63.0	64.2	66.5	68.8	69.9	70.5	*
15 years	270	68.3	0.24	*	64.4	65.1	66.6	68.8	70.1	70.9	71.7	*
16 years	308	69.2	0.26	64.6	65.7	66.1	67.1	69.3	71.0	72.4	73.6	74.3
17 years	278	69.5	0.19	*	65.9	66.4	67.4	69.6	71.5	72.2	72.9	*
18 years	284	69.6	0.21	*	65.8	66.7	67.9	69.4	71.4	72.2	73.3	*
19 years	271	69.6	0.36	*	65.1	66.1	67.3	69.8	71.8	73.0	73.5	*
Female												
2 years	285	35.5	0.15	*	33.1	33.4	34.3	35.5	36.7	37.2	37.6	*
3 years	187	38.7	0.14	*	36.2	36.9	37.8	38.6	40.0	40.5	41.0	*
4 years	225	41.4	0.16	*	39.1	39.6	40.1	41.4	42.5	43.5	44.1	*
5 years	199	44.2	0.21	*	41.4	41.6	42.3	44.0	45.9	46.8	47.1	*
6 years	193	46.9	0.21	*	44.4	44.6	45.2	46.6	48.4	49.5	50.2	*
7 years	157	49.5	0.30	*	46.5	47.0	47.8	49.5	50.9	51.8	52.4	*
8 years	184	51.7	0.21	*	48.5	48.9	49.9	51.4	53.2	54.3	54.6	*
9 years	185	54.5	0.28	*	51.2	51.7	52.5	54.5	56.6	57.5	57.9	*
10 years	189	56.8	0.29	*	53.2	53.9	54.6	56.6	58.5	59.6	60.1	*
11 years	174	59.6	0.27	*	55.6	56.6	57.6	59.6	61.8	63.0	63.5	*
12 years	249	61.7	0.22	*	58.4	58.8	59.8	61.7	63.3	64.6	65.6	*
13 years	292	62.4	0.24	57.9	59.1	59.5	60.5	62.1	64.2	65.6	66.1	67.1
14 years	270	63.2	0.23	*	59.3	60.0	61.3	63.4	65.0	65.9	66.7	*
15 years	254	63.8	0.24	*	60.7	61.4	62.4	63.8	65.3	66.3	67.0	*
16 years	261	64.1	0.23	*	60.5	60.9	61.8	64.1	66.4	67.5	67.9	*
17 years	275	63.9	0.16	*	61.3	61.8	62.4	63.8	65.4	66.1	66.6	*
18 years	304	64.2	0.19	59.8	60.9	61.5	62.3	64.1	66.0	66.8	67.3	68.2
19 years	267	64.2	0.23	*	60.3	61.2	62.2	64.3	66.1	67.0	67.9	*

Table F.5: Height in inches for females 20 years of age and older by race and ethnicity and age, by mean, standard error of the mean, and selected percentiles: United States, 2003-2006

Race and ethnicity and age	Number examined	Mean	Standard error	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All race and ethnicity groups[1]								Inches				
20 years and over	4,857	63.8	0.06	59.3	60.3	61.0	62.1	63.8	65.6	66.6	67.2	68.2
20–29 years	1,061	64.3	0.12	59.9	60.9	61.6	62.5	64.2	66.1	66.9	67.5	68.0
30–39 years	842	64.3	0.13	60.0	60.8	61.5	62.5	64.2	66.0	67.1	67.7	68.6
40–49 years	784	64.2	0.12	59.9	60.6	61.4	62.4	64.2	66.0	66.9	67.7	68.5
50–59 years	604	63.9	0.13	59.3	60.4	61.2	62.2	63.8	65.7	66.4	67.1	67.9
60–69 years	691	63.7	0.13	59.8	60.5	61.1	62.1	63.7	65.3	66.1	66.9	67.5
70–79 years	463	62.7	0.13	58.6	59.4	60.1	61.0	62.6	64.4	65.2	65.9	66.7
80 years and over	412	61.4	0.15	57.5	58.3	58.8	59.7	61.3	62.9	63.9	64.7	65.4
Non-Hispanic white												
20 years and over	2,477	64.2	0.06	59.9	60.8	61.5	62.5	64.2	66.0	66.8	67.5	68.4
20–39 years	866	64.9	0.09	60.9	61.9	62.4	63.3	64.8	66.5	67.4	67.9	68.7
40–59 years	677	64.4	0.11	60.1	61.2	62.0	62.8	64.3	66.0	66.9	67.6	68.5
60 years and over	934	63.1	0.11	58.9	59.8	60.5	61.4	62.9	64.8	65.6	66.4	67.1
Non-Hispanic black												
20 years and over	1,035	64.1	0.10	59.7	60.6	61.2	62.3	64.0	65.8	66.8	67.3	68.4
20–39 years	407	64.3	0.17	59.7	60.9	61.5	62.4	64.2	65.9	67.0	67.6	68.7
40–59 years	355	64.3	0.16	59.9	60.7	61.4	62.5	64.4	65.9	66.8	67.4	68.4
60 years and over	273	63.2	0.12	59.1	60.1	60.5	61.5	63.2	65.0	65.7	66.5	67.1
Mexican American												
20 years and over	975	62.1	0.10	58.0	59.0	59.5	60.5	62.1	63.7	64.7	65.4	66.2
20–39 years	455	62.5	0.13	58.3	59.3	60.1	60.9	62.6	64.0	64.9	65.6	66.5
40–59 years	238	62.1	0.19	*	59.0	59.5	60.4	62.0	63.7	64.6	65.3	*
60 years and over	282	60.6	0.19	57.1	57.4	58.0	59.1	60.6	62.2	62.9	63.6	64.7

Table F.6: Height in inches for males 20 years of age and older by race and ethnicity and age, by mean, standard error of the mean, and selected percentiles: United States, 2003-2006

Race and ethnicity and age	Number examined	Mean	Standard error	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All race and ethnicity groups[1]								Inches				
20 years and over	4,482	69.4	0.07	64.4	65.6	66.3	67.4	69.4	71.5	72.6	73.2	74.3
20–29 years	808	69.9	0.13	64.7	65.8	66.6	67.8	70.0	72.0	73.0	73.5	74.8
30–39 years	742	69.4	0.13	64.1	65.3	66.1	67.5	69.5	71.5	72.7	73.4	74.7
40–49 years	769	69.7	0.11	65.2	66.2	66.8	67.9	69.7	71.6	72.7	73.3	74.0
50–59 years	591	69.5	0.15	65.0	65.8	66.5	67.5	69.5	71.5	72.7	73.4	74.4
60–69 years	668	69.0	0.11	64.2	65.4	66.1	67.1	69.0	71.1	71.9	72.7	73.7
70–79 years	555	68.4	0.16	63.8	64.6	65.5	66.4	68.5	70.3	71.0	72.0	73.1
80 years and over	349	67.2	0.14	62.7	63.6	64.3	65.5	67.2	68.9	70.0	70.5	71.3
Non-Hispanic white												
20 years and over	2,331	69.9	0.08	65.4	66.3	67.0	68.0	69.8	71.8	72.8	73.4	74.5
20–39 years	664	70.4	0.10	65.9	67.0	67.7	68.6	70.4	72.2	73.1	73.9	74.9
40–59 years	710	70.1	0.14	65.9	66.6	67.3	68.2	70.0	72.0	72.9	73.5	74.3
60 years and over	957	68.8	0.08	64.0	65.0	65.8	66.8	68.8	70.7	71.7	72.3	73.4
Non-Hispanic black												
20 years and over	943	69.8	0.08	65.1	66.1	66.9	67.8	69.7	71.6	72.7	73.4	74.6
20–39 years	361	70.1	0.14	65.5	66.1	67.0	68.1	70.0	72.0	72.9	73.7	75.1
40–59 years	316	69.8	0.13	65.4	66.4	67.0	68.0	69.8	71.5	72.7	73.5	74.4
60 years and over	266	68.6	0.20	64.2	64.9	65.7	66.7	68.5	70.5	71.6	72.2	73.1
Mexican American												
20 years and over	902	67.0	0.13	62.5	63.4	64.2	65.0	67.1	68.8	69.7	70.5	71.6
20–39 years	375	67.2	0.18	62.3	63.5	64.3	65.1	67.1	69.0	69.9	71.1	72.3
40–59 years	246	67.0	0.16	62.8	63.6	64.3	65.2	67.2	68.9	69.4	70.1	70.9
60 years and over	281	66.1	0.17	62.1	62.7	63.3	64.3	66.1	67.9	68.4	68.9	69.6

Appendix G: Interview List and Questions

Interview List:

- Ethical and Legal Issues:
    - Kent Rissmiller , PhD
- Passenger Vessel Companies:
    - The Potomac Belle – George Stevens
    - The Potomac Riverboat Co.
        - Capt. John Lake
            - → Operator
        - Ms. Charlotte Hall
            - → VP Business
    - Entertainment Cruises
        - Capt. Mike Brook
            - → Operator
        - Ms. Linda Circo
            - → Director of Sales
    - Watermark – Ms. Debbie Gosselin

Interview Questions:

*Note that these were used as a guideline; not all questions were asked if they did not apply to the company's vessels or business

- Operations Manager Questions:
    - Explanation of project
    - What is your operating season?
    - What types of boats do you have? What is the purpose of your boat(s)?
    - What is the length and hull type of your boat(s)?
    - When during your season are you busiest (time of season, time of day)?
    - How many voyages per day do you make?
    - How often is your boat(s) at 90% capacity or higher?
    - What is the maximum # of people your vessel can carry?
    - What effects do you see on your boat when it is at full load v. not full?
    - Do you use any other method of monitoring your vessel's weight other than counting passengers?
    - Is your vessel weight-limited or limited by surface area?
    - Do you sell concessions onboard your vessel?
    - Can you estimate the total weight of the concessions you carry?

- Business Manager Questions:
    - Explanation of project
    - Can you give us a brief overview of the business?
    - What is the cost of each ticket?
    - How much money would you estimate that each passenger spends on a single voyage?
    - How do think the increase in average passenger weight would affect your business/company?
    - In your opinion, would it be more of a financial burden to have your vessel re-certificated with the new Coast Guard average passenger weight or implement a solution that would inform the captain if the vessel is overweight?
    - In what price range would your company be willing to spend to implement a solution that would inform the captain if the vessel is over weight?

Appendix H: Interview Results

Interview with Professor Rissmiller (Legal Specialist)

Date: October 3, 2008
Location: Worcester Polytechnic institute AK124
Attendees: Molli Malcolmson, Daniel Sacco, Professor Rissmiller
Secretary: Daniel Sacco
Start Time: 2:05PM End Time: 2:40PM

- To begin the interview we described our ferry boat overloading project to Professor Rissmiller. We had a set of questions we wanted to ask him regarding legal privacy issues that are involved with our project. However, once we finished describing our project, Professor Rissmiller began talking about how he sees our situation and effectively answered all of our questions before we were able to ask them.
- Professor Rissmiller said that privacy is related to needs. To a person, privacy is defined differently depending on the situation.
- Professor Rissmiller also said that from a legal stand point we don't have very much to worry about as far as privacy issues. Legally, things that are defined as private are social security numbers, bank information, etc. What we are dealing with is more a "personal" issue than a "privacy" issue. People might believe that their weight is a private thing but it is really only personal and therefore does not technically fall any legal laws.
- The government has determined that anything in a public place is public information. This means that video recording and taking pictures in public places are allowed even though some people might not like it. Theoretically, a person's weight could be very easily estimated if a picture of someone was taken and their body dimensions were measured.
- Professor Rissmiller suggested that methods for estimating the body weight of people boarding ferries may be a good solution. It can be fast, fairly accurate, and people won't feel like their privacy is being invaded as much as if their weight were being directly measured. This could probably be done very effectively with a screening device. People can be classified into categories depending on height, gender, body shape, and whether they are a child or an adult. Then these categories can have average weights associated with them. Experiments and studies can be done to determine what average weights are appropriate for each category.
- People will probably be okay with their weight being estimated if they know that the only reason for it is safety. They will also expect that their weight will not be associated with their names and no one else will be notified of the information.
- An important point that we need to watch out for in our project is discrimination. We need to make sure that we treat everyone equally, and as Professor Rissmiller said, that we "Don't reach farther than we need to."

- Professor Rissmiller also suggested looking into how airlines determine their weight since this might provide useful information into how we can solve our problem.
- Molli asked Professor Rissmiller how state laws might affect our project. Professor Rissmiller said that state laws deal mostly with criminal situations and should have no effect on our project.
- Professor Rissmiller restated that what we are dealing with is a “personal” issue and not a “private” one. What we need to watch out for is making sure no one gets discriminated against and making sure we provide people with a reasonable level of “personal” privacy. Of course this reasonable level is always changing and evolving.

Interview with Mr. George Stevens of the Potomac Belle

Date: November 7, 2008

Location: Alexandria, VA

Attendees: Molli Malcolmson, Daniel Sacco, Thomas Whiting, Mr. George Stevens

- Purpose of Vessel: Private Charters
- Boat info: shallow draft hull (about 23”) – exceptionally wide – 59’ long
- Coast Guard rated for 49 people – only take 35 at most per voyage
- Season: 1st weekend in April to mid November
- Busiest: Mid May through September
- Usually make 1 voyage per day – sometimes (but rarely) 2 voyages per day
- Base/hourly rate – $1650 for 3 hours (Mon-Thurs); $1875 for 3 hours (Fri-Sun)
- No Concessions – Bring your own/ hire a caterer (about 95% bring own food and don’t use a caterer)
- Gave us a brochure
- His boat is probably unaffected by the change in average weight
- Since 9-11 the Coast Guard constantly patrols the river and harbors

Interview with Captain John Lake of The Potomac Riverboat Company

Date: November 7, 2008

Location: Alexandria, VA

Attendees: Molli Malcolmson, Daniel Sacco, Thomas Whiting, Capt. John Lake

- 7 vessels – of the seven the two water taxis are sister ships
- Cherry Blossom – technically open year round; really no business during Jan & Feb, charter/reservation only
- Rest of vessels are tour boats and water taxis sometimes used for private charter (2 water taxis, 4 tour boats); season: April-Oct – 7 days a week from memorial day to labor day

- Run Mt. Vernon trip once a day
- Tours run from 11am-12pm give or take an hour
- Georgetown trip takes 1 ½ hrs. including docking and boarding
- Usually a 7-10 minute wait for water taxis
- Amount of people on vessels is weather dependant
  - Slower on weekdays – usually 20-30 people
  - Busy on weekends – pushing 149 people (runs 3-7pm on Sat)
    - Cherry Blossom capacity is 400 people
    - This is info relates to three larger tour boats (COI capacity of 149 people)
    - Smaller tour boat (36’) COI capacity is 80 people, stability is 92
    - Water Taxis COI capacity is 99 people – usually run with no more than 92 – stability allows 153 passengers, choose to hold at 149 because of regulations
- Boats with 99 passengers need to have 1 deck hand
- Boats that carry less than or equal to 149 passengers fall into subchapter T
- Boats that carry more than 149 passengers fall into subchapter K
- Sometimes it’s cheaper to take out 2 taxis instead of 1
- Peak taxi hours are 3pm to 7pm on week days
- Inclined v. Simple Stability tests
  - Inclined usually done when ship is first constructed
    - Cost usually $10-12 thousand depending upon ship class (T or K)
  - SST usually done when ship has been modified or if owner wants to increase # of passengers allowed on the ship
    - Cost usually a couple grand
- Concessions- only water on taxis – yes everywhere else – soda, beer, water, and popcorn
- Depending upon the boat- you may see a difference in where the smaller boats sit in the water but not in the larger boats; for all the boats you can feel a difference
- They count passengers through a ticketing system- used to not oversell voyages
  - Only sell 140 tickets
    - Leaves a cushion especially for small children
  - Can buy tickets at booth on dock or ahead of time online
- Sometimes see luggage on water taxis but not on other vessels
- Extra compartment weight is not accounted for in original SST
- They are looking into doing an airport shuttle boat in the future
- Water taxis are usually at the dock for about 7-10 minutes

- Sometimes people run up last minute to get on
- Ticket booth has 3 windows
- Taxis get a lot of impulse buys

Interview with Ms. Charlotte Hall of The Potomac Riverboat Company

Date: November 7, 2008

Location: Alexandria, VA

Attendees: Molli Malcolmson, Daniel Sacco, Thomas Whiting, Ms. Charlotte Hall

- Financial Effects would depend upon pricing – two stops – hotel and harbor wanted their own taxis
- Highest volume of people at Gaylord, paperwork is in to increase capacity
- Admiral Tilp certified for 80 people usually 50 people for parties
- Timmy Redmon – operations manager of Spirit Cruises (202) 439-2270
- Bill Ross- (202) 369-7077; bought small pontoon boat operates out of Georgetown
- Debbie Gauzlen – Annapolis – Watermark: (301) 261- 2719 x 103
    - Working with PAV to try out new security system
- Contact:
    - Pintail Yachts
    - Black-eyed Susan
- Depending upon who owns dock they may or may not charge you to dock there; definitely an insurance fee though
    - Potomac Riverboat Company not charged in Georgetown
    - Alexandria/National Harbor: lease from city (10 year lease from Alexandria)
    - Mt. Vernon- charged $1 per passenger – after hours they pay a docking fee and an afterhours fee
- Water taxi v. ferry:
    - Ferry carries cars – water taxi does not
- Old Town Trolley company owns DC Ducks
    - Frank Fraker
- Caterers have to have two types of insurance
- Passenger Vessel Association is in Alexandria
- Occasionally customers take 95 people on one of the boats when the limit is 99
- Sometimes canine cruises/pirate cruises

Interview with Captain Mike Brook of Entertainment Cruises

Date: November 7, 2008

Location: Washington, D.C.

Attendees: Molli Malcolmson, Daniel Sacco, Thomas Whiting, Capt. Mike Brook, Ms. Linda Circo

- Open year round
    - about 90,000 passengers a year
    - Peak Season: March-July due to traveling and influx of students
        - 2 cruises/boat/day
        - Dinner/lunch cruises
        - Tours cruises to Mt. Vernon
    - Non-peak season: 2-3 Cruises per week
        - Tour cruises to Mt. Vernon
- Cruises can be public or chartered
- Odyssey/Spirit can hold up to 600 (574) according to COI; Capital Elite can hold up to 110
- Capital Elite lost 40 passengers off their limit recently due to recertification
- River is considered protected waters
- Not at 100% capacity very often – 5-6 time/year
    - Cruise seats 425 passengers comfortably
    - Avg. 300-400 passengers
- Use ticket counting (program mentioned above) to count how many passengers are onboard (no other method for determining load is used)
    - Also use draft marks on the sides of the larger ships (effective for larger ships) on ship 600 passengers = 1' of displacement near draft mark
- Light ship- day to day necessities that are taken into account in stability tests
    - Fuel
    - Water
    - Sewage
    - Food, liquor
    - Tables
- In doing calculations worst case scenario is used (fire in the basement etc.)
- Opinion: New Passenger weight is a good thing – most boats won't be effected

Interview with Ms. Linda Circo of Entertainment Cruises

Date: November 7, 2008

Location: Washington, D.C.

Attendees: Molli Malcolmson, Daniel Sacco, Thomas Whiting, Ms. Linda Circo

- Entertainment Cruises have ships in 7 different Cities:
    - Philly, Baltimore, DC, Chicago, Boston, New York City, Norfolk
- Spirit Cruises in Baltimore – Chip is the operations manager there
- *Capital Elite* is one of the ships in DC
    - between 91' in length 2 decks
    - holds an average of 48-50 guests

    - carried more people, but now has to carry less
        - underwent another stability test after ***Ethan Allen***
- Inclusive Package – food, entertainment – bar is usually an add on
- Business breakdown:
    - 75% of business is group business = 20+ guests
    - 25% of business is small parties
- Most food and liquor is not stored on the boat
- Spirit and Odyssey are loaded for individual voyages
- EBMS- their program that is used to help prevent overselling tickets
- Almost all tickets are pre-sold with the exception of the Spirit of Mt. Vernon
    - 25% is walk up business
    - Navy-Pier gets more walk up business because more people are walking around there
- Prices range from $15 dollars on the seadog to $125 dollars on the Odyssey
- Boats are licensed for 600 guests but usually don't carry more than 400
- There is a child rate and an adult rate
- They do allow wheelchairs – usually have to decrease the number of people they allow to sit a table because of the size of the wheelchairs

Interview with Ms. Debbie Gosselin of Watermark

Date: November 7, 2008

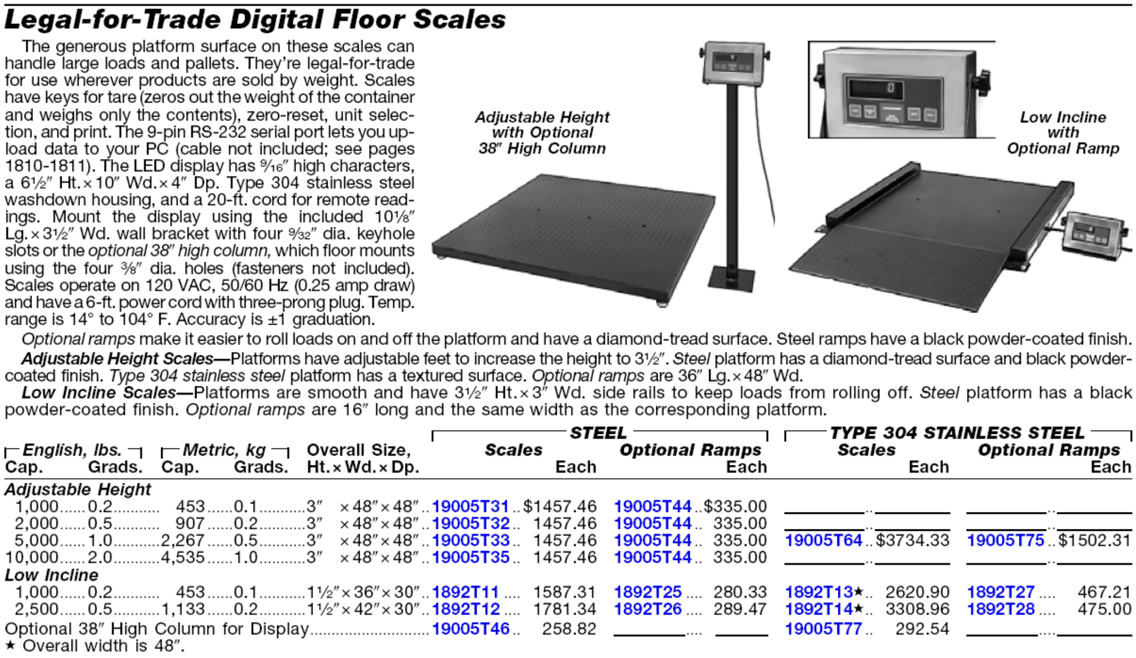
Location: Washington, D.C.

Attendees: Molli Malcolmson, Ms. Debbie Gosselin (phone interview)

- Runs 11 tour, charter, water taxi vessels total
- No pontoon boats
- Operating season March thru December
- Busiest season Memorial – Labor Day
- Voyages per day vary- 75 for water taxis on a busy weekend – scheduled tours
- 2 K vessels, 9 T vessels; 80% of the time they are filled to 90% capacity- most money when they are filled
- Opinion of change in CG Regulations:
    - Understands the need for increase in average passenger weight- way cg wants vessels to defend their stability all the time is unreasonable- why is it necessary when some companies have been running for years without problems, and there has yet to be a case of an accident where overloading was to blame
- Other info:
    - They are looking at $50,000 in stability testing fees; fee money that they will have to pay for due to the increase in how often they will have to renew their certification.

Appendix I: Examples of Scales

Examples of scales we found that can be used for measuring either individual people or groups of people:



Legal-for-Trade Digital Floor Scales

The generous platform surface on these scales can handle large loads and pallets. They're legal-for-trade for use wherever products are sold by weight. Scales have keys for tare (zeros out the weight of the container and weighs only the contents), zero-reset, unit selection, and print. The 9-pin RS-232 serial port lets you upload data to your PC (cable not included; see pages 1810-1811). The LED display has 9⁄16″ high characters, a 6½″ Ht. × 10″ Wd. × 4″ Dp. Type 304 stainless steel washdown housing, and a 20-ft. cord for remote readings. Mount the display using the included 10⅛″ Lg. × 3½″ Wd. wall bracket with four 9⁄32″ dia. keyhole slots or the *optional 38″ high column,* which floor mounts using the four ⅜″ dia. holes (fasteners not included). Scales operate on 120 VAC, 50/60 Hz (0.25 amp draw) and have a 6-ft. power cord with three-prong plug. Temp. range is 14° to 104° F. Accuracy is ±1 graduation.

Optional ramps make it easier to roll loads on and off the platform and have a diamond-tread surface. Steel ramps have a black powder-coated finish.

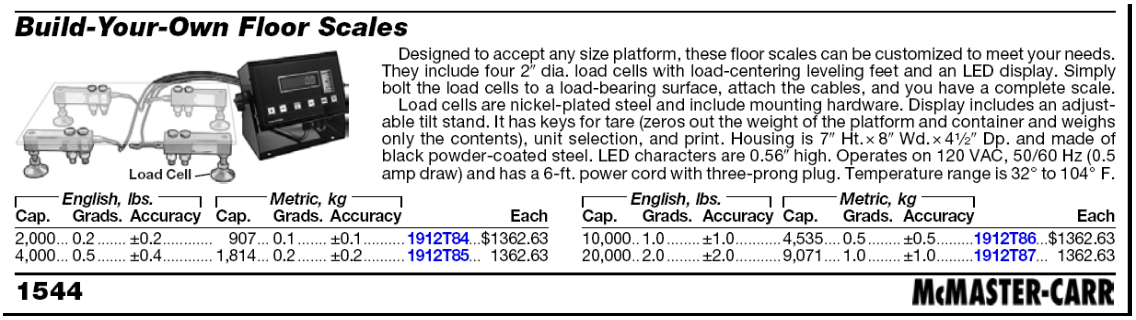
Adjustable Height Scales—Platforms have adjustable feet to increase the height to 3½″. *Steel* platform has a diamond-tread surface and black powder-coated finish. *Type 304 stainless steel* platform has a textured surface. *Optional ramps* are 36″ Lg. × 48″ Wd.

Low Incline Scales—Platforms are smooth and have 3½″ Ht. × 3″ Wd. side rails to keep loads from rolling off. *Steel* platform has a black powder-coated finish. *Optional ramps* are 16″ long and the same width as the corresponding platform.

English, lbs.		*Metric, kg*		Overall Size,	*STEEL*				*TYPE 304 STAINLESS STEEL*			
					Scales		*Optional Ramps*		*Scales*		*Optional Ramps*	
Cap.	Grads.	Cap.	Grads.	Ht. × Wd. × Dp.		Each		Each		Each		Each
Adjustable Height												
1,000	0.2	453	0.1	3″ × 48″ × 48″	19005T31	$1457.46	19005T44	$335.00				
2,000	0.5	907	0.2	3″ × 48″ × 48″	19005T32	1457.46	19005T44	335.00				
5,000	1.0	2,267	0.5	3″ × 48″ × 48″	19005T33	1457.46	19005T44	335.00	19005T64	$3734.33	19005T75	$1502.31
10,000	2.0	4,535	1.0	3″ × 48″ × 48″	19005T35	1457.46	19005T44	335.00				
Low Incline												
1,000	0.2	453	0.1	1½″ × 36″ × 30″	1892T11	1587.31	1892T25	280.33	1892T13★	2620.90	1892T27	467.21
2,500	0.5	1,133	0.2	1½″ × 42″ × 30″	1892T12	1781.34	1892T26	289.47	1892T14★	3308.96	1892T28	475.00
Optional 38″ High Column for Display					19005T46	258.82			19005T77	292.54		

★ Overall width is 48″.

Figure I.1: Floor Scales (McMaster-Carr, 2008)



Build-Your-Own Floor Scales

Designed to accept any size platform, these floor scales can be customized to meet your needs. They include four 2″ dia. load cells with load-centering leveling feet and an LED display. Simply bolt the load cells to a load-bearing surface, attach the cables, and you have a complete scale.

Load cells are nickel-plated steel and include mounting hardware. Display includes an adjustable tilt stand. It has keys for tare (zeros out the weight of the platform and container and weighs only the contents), unit selection, and print. Housing is 7″ Ht. × 8″ Wd. × 4½″ Dp. and made of black powder-coated steel. LED characters are 0.56″ high. Operates on 120 VAC, 50/60 Hz (0.5 amp draw) and has a 6-ft. power cord with three-prong plug. Temperature range is 32° to 104° F.

English, lbs.			*Metric, kg*					*English, lbs.*			*Metric, kg*				
Cap.	Grads.	Accuracy	Cap.	Grads.	Accuracy		Each	Cap.	Grads.	Accuracy	Cap.	Grads.	Accuracy		Each
2,000	0.2	±0.2	907	0.1	±0.1	1912T84	$1362.63	10,000	1.0	±1.0	4,535	0.5	±0.5	1912T86	$1362.63
4,000	0.5	±0.4	1,814	0.2	±0.2	1912T85	1362.63	20,000	2.0	±2.0	9,071	1.0	±1.0	1912T87	1362.63

1544 McMASTER-CARR

Figure I.2: Build-Your-Own Floor Scale (McMaster-Carr, 2008)

Listing of: Best Buys - DC-44-5K Scale

DC-44-5K Scale

Non-Ntep floor scale with HL-2065 Dolphin indicator included. 4'x4'. 5,000lb capacity.

Included Items

HL-2065 Dolphin

- **RUGGED** - Durable platform design withstands heavy industrial use. 200% overload capacity, 100% end-load capacity. Sum capacity of load cells is twice scale capacity. 100% mig welded Structural-Steel construction
- **ALL PURPOSE** - Easy to install. Levels with lugs (no shimming). Easy to relocated. Full line of accessories available.
- **HIGHEST QUALITY** - Uses shear beam load cells. All structural bracing is structural steel channel iron.

$599.00

Figure I.3: Dolphin Floor Scale (Best Buy Scale, 2008)

LifeSource UC-321 Precision Personal Health Scale

Other products by LifeSource

★★★★☆ (16 customer reviews)

List Price: ~~$149.95~~

Price: $97.00

You Save: $52.95 (35%)

In Stock.

Ships from and sold by **Healthcheck Systems Inc**.

Ordering for Christmas? Based on the shipping schedule of Healthcheck Systems Inc, choose **Standard Shipping** at checkout for delivery by December 24. See Healthcheck Systems Inc shipping details.

4 used & new available from $97.00

Figure I.4: Personal Scale (Amazon, 2008)

Appendix J: Load Lines on Vessel

This is the type of drawing that would be seen on the side of a vessel. It is located amidships on the vessel. A vertical line is painted 21” forward of the center of the ring (Office of Federal Register National Archives and Records Administration, 2004).

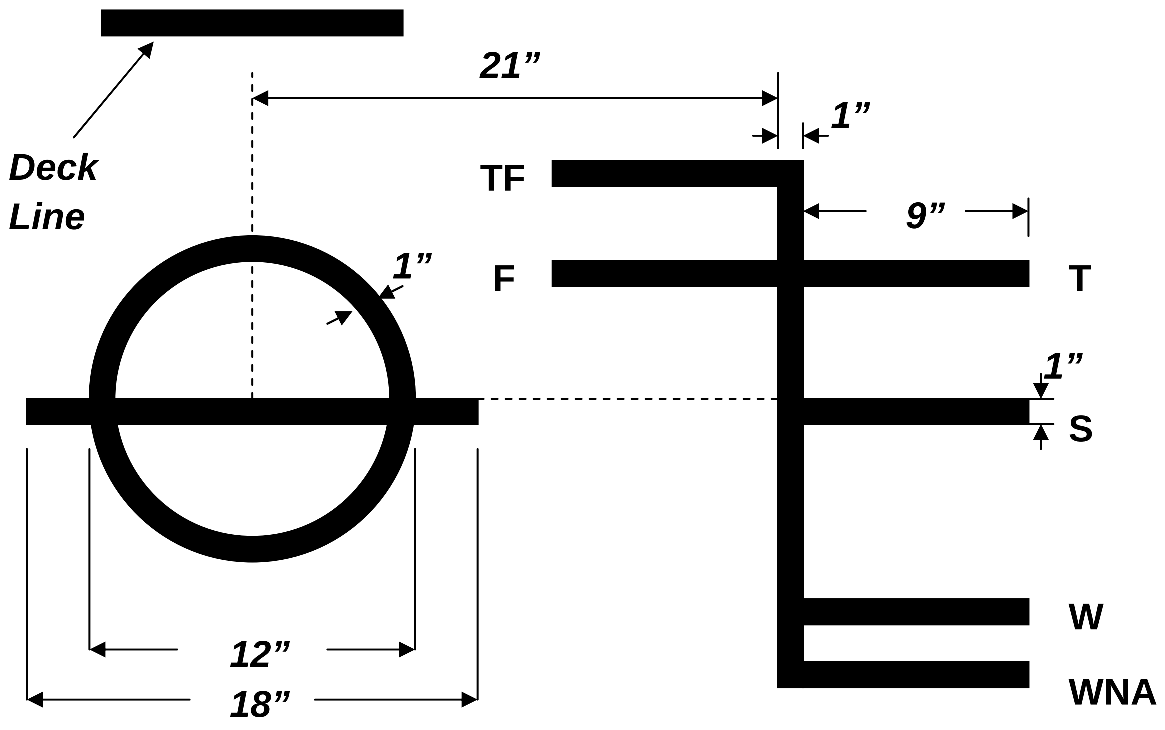


Figure J.1: Load Lines

S = Summer load mark, upper edge of the line passes through the center of the ring

W = Winter load mark

WNA = Winter North Atlantic load mark

T = Tropical load mark

F = Fresh water load mark

TF = Tropical fresh water load mark

*Each of these marks is 9” by 1”, and cannot be fully submerged when determining if vessel is overweight.

Appendix K: FAA Segmented Weight Tables

(See Section 4.1.2 Average Weight Methods for more details.)

Table K.1: Ratio of Males to Females with Corresponding Average Passenger Weight

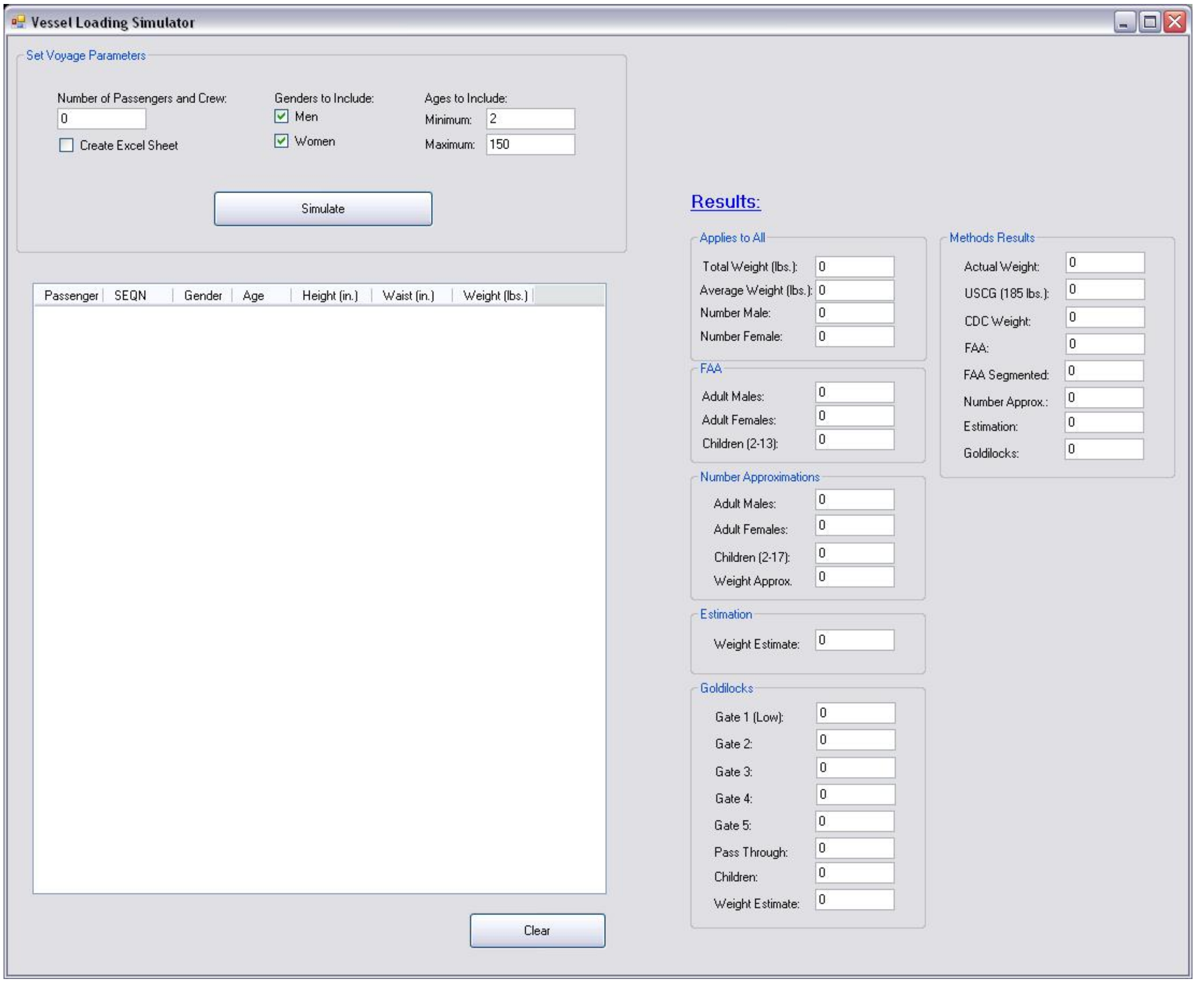
	0/100	5/95	10/90	15/85	20/80	25/75	30/70	35/65	40/60	45/55	50/50	55/45	60/40	65/35	70/30	75/25	80/20	85/15	90/10	95/5	100/0
5	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245
6-8	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233
9-11	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223
12-16	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217
17-25	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212
26-30	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208
31-53	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205
54+	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202

Table K.2: Segmented Weights for up to Ten Males and Ten Females

		Number of Females										
		0	1	2	3	4	5	6	7	8	9	10
	0						1125	1278	1491	1704	1827	2030
	1		Doesn't apply, too small.			1145	1296	1512	1728	1845	2050	2255
	2				1165	1320	1533	1744	1863	2070	2277	2400
	3			1185	**1338**	1554	1768	1890	2090	2288	2424	2626
Number of Males	4		1205	1356	1568	**1784**	1908	2110	2310	2448	2639	2842
	5	1225	1380	1589	1808	1926	**2130**	2332	2460	2665	2856	3060
	6	1398	1610	1824	1944	2150	2354	**2484**	2678	2884	3075	3280
	7	1631	1848	1971	2170	2376	2508	2704	**2898**	3090	3296	3400
	8	1864	1989	2190	2398	2520	2717	2912	3120	**3312**	3417	3618
	9	2007	2210	2409	2544	2743	2940	3135	3328	3451	**3636**	3819
	10	2230	2431	2568	2756	2954	3150	3360	3468	3654	3857	**4040**

Appendix L: Vessel Loading Simulator

To analyze several of our possible solutions for accuracy we simulated different vessel loading simulations using real biometric data of actual people in the United States. To generate these simulations we wrote a program using the Microsoft Visual Basic programming language. The user interface for this software is shown below. Refer to section 3.3.4 for more information.



Number of Passengers and Crew: 0
☐ Create Excel Sheet
Genders to Include:
☑ Men
☑ Women
Ages to Include:
Minimum: 2
Maximum: 150

Total Weight (lbs.): 0
Average Weight (lbs.): 0
Number Male: 0
Number Female: 0

Adult Males: 0
Adult Females: 0
Children (2-13): 0

Adult Males: 0
Adult Females: 0
Children (2-17): 0
Weight Approx. 0

Weight Estimate: 0

Gate 1 (Low): 0
Gate 2: 0
Gate 3: 0
Gate 4: 0
Gate 5: 0
Pass Through: 0
Children: 0
Weight Estimate: 0

Actual Weight: 0
USCG (185 lbs.): 0
CDC Weight: 0
FAA: 0
FAA Segmented: 0
Number Approx.: 0
Estimation: 0
Goldilocks: 0

Figure L.1: Vessel Loading Simulator

Appendix M: Dock Space

The following figures provide examples of docks that passenger vessel companies use. We found that most of the companies we visited did not have a lot of dock space available to implement possible solutions.

Figure M.1: Dock Space Shared by Four Charter Fishing Vessels

11/24/2008

Figure M.2: Dock Space used by a Passenger Vessel

11/24/2008

Figure M.3: Dock Space used by a Charter Fishing Vessel

Appendix N: Simulation Data

Table N.1: Simulation Results

Sample #	Total People	Age Groups	Gender Ratio	Total Males	Total Females	Children (2-13)	Children (2-17)	Average Weight	Actual Weight
1	25	2+	All Male	25	0	11	13	119	2,779
2	25	2+	All Male	25	0	7	11	150	3,746
3	25	2+	All Male	25	0	12	14	127	3,184
4	25	2+	All Male	25	0	12	15	121	3,029
5	25	2+	All Male	25	0	8	10	150	3,746
6	25	2+	All Female	0	25	11	14	115	2,875
7	25	2+	All Female	0	25	8	13	128	3,212
8	25	2+	All Female	0	25	10	11	119	2,981
9	25	2+	All Female	0	25	5	8	152	3,806
10	25	2+	All Female	0	25	10	13	121	3,020
11	25	2+	Mixed	14	11	7	10	143	3,586
12	25	2+	Mixed	12	13	11	16	133	3,321
13	25	2+	Mixed	12	13	6	9	156	3,888
14	25	2+	Mixed	11	14	4	8	155	3,864
15	25	2+	Mixed	14	11	8	13	120	2,998
16	25	21+	All Male	25	0	0	0	200	5,002
17	25	21+	All Male	25	0	0	0	184	4,590
18	25	21+	All Male	25	0	0	0	202	5,044
19	25	21+	All Male	25	0	0	0	189	4,725
20	25	21+	All Male	25	0	0	0	203	5,073
21	25	21+	All Female	0	25	0	0	166	4,146
22	25	21+	All Female	0	25	0	0	169	4,220
23	25	21+	All Female	0	25	0	0	172	4,295
24	25	21+	All Female	0	25	0	0	173	4,317
25	25	21+	All Female	0	25	0	0	165	4,131
26	25	21+	Mixed	11	14	0	0	190	4,752
27	25	21+	Mixed	14	11	0	0	181	4,525
28	25	21+	Mixed	13	12	0	0	180	4,498
29	25	21+	Mixed	12	13	0	0	174	4,354
30	25	21+	Mixed	12	13	0	0	177	4,431
31	49	2+	All Male	49	0	16	24	144	7,050
32	49	2+	All Male	49	0	15	26	144	7,034
33	49	2+	All Male	49	0	22	23	145	7,084
34	49	2+	All Male	49	0	16	20	144	7,079
35	49	2+	All Male	49	0	14	24	153	7,490
36	49	2+	All Female	0	49	15	27	135	6,621
37	49	2+	All Female	0	49	18	21	141	6,887
38	49	2+	All Female	0	49	11	20	131	6,414
39	49	2+	All Female	0	49	14	19	135	6,592
40	49	2+	All Female	0	49	20	27	124	6,097
41	49	2+	Mixed	21	28	14	19	150	7,374
42	49	2+	Mixed	23	26	13	19	148	7,238

Sample #	Total People	Age Groups	Gender Ratio	Total Males	Total Females	Children (2-13)	Children (2-17)	Average Weight	Actual Weight
43	49	2+	Mixed	31	18	19	23	145	7,082
44	49	2+	Mixed	21	28	14	19	153	7,522
45	49	2+	Mixed	25	24	17	22	136	6,675
46	49	21+	All Male	49	0	0	0	198	9,711
47	49	21+	All Male	49	0	0	0	196	9,622
48	49	21+	All Male	49	0	0	0	201	9,840
49	49	21+	All Male	49	0	0	0	182	8,932
50	49	21+	All Male	49	0	0	0	193	9,445
51	49	21+	All Female	0	49	0	0	166	8,147
52	49	21+	All Female	0	49	0	0	164	8,025
53	49	21+	All Female	0	49	0	0	162	7,959
54	49	21+	All Female	0	49	0	0	149	7,324
55	49	21+	All Female	0	49	0	0	164	8,045
56	49	21+	Mixed	22	27	0	0	172	8,451
57	49	21+	Mixed	28	21	0	0	178	8,710
58	49	21+	Mixed	30	19	0	0	192	9,417
59	49	21+	Mixed	18	31	0	0	181	8,856
60	49	21+	Mixed	30	19	0	0	191	9,357
61	149	2+	All Male	149	0	39	59	157	23,384
62	149	2+	All Male	149	0	45	66	153	22,811
63	149	2+	All Male	149	0	51	73	144	21,435
64	149	2+	All Male	149	0	51	73	146	21,830
65	149	2+	All Male	149	0	47	60	154	22,932
66	149	2+	All Female	0	149	42	58	141	20,979
67	149	2+	All Female	0	149	42	61	137	20,472
68	149	2+	All Female	0	149	38	58	137	20,455
69	149	2+	All Female	0	149	44	52	138	20,598
70	149	2+	All Female	0	149	43	61	133	19,790
71	149	2+	Mixed	70	79	49	65	140	20,865
72	149	2+	Mixed	68	81	42	61	144	21,490
73	149	2+	Mixed	67	82	37	67	149	22,227
74	149	2+	Mixed	66	83	42	58	138	20,545
75	149	2+	Mixed	74	75	43	66	142	21,176
76	149	21+	All Male	149	0	0	0	190	28,263
77	149	21+	All Male	149	0	0	0	196	29,142
78	149	21+	All Male	149	0	0	0	193	28,693
79	149	21+	All Male	149	0	0	0	190	28,260
80	149	21+	All Male	149	0	0	0	193	28,782
81	149	21+	All Female	0	149	0	0	168	25,103
82	149	21+	All Female	0	149	0	0	168	24,975
83	149	21+	All Female	0	149	0	0	170	25,353
84	149	21+	All Female	0	149	0	0	169	25,128
85	149	21+	All Female	0	149	0	0	164	24,501
86	149	21+	Mixed	71	78	0	0	177	26,298
87	149	21+	Mixed	73	76	0	0	179	26,677
88	149	21+	Mixed	69	80	0	0	183	27,261
89	149	21+	Mixed	66	83	0	0	181	26,016
90	149	21+	Mixed	77	72	0	0	179	26,729