Abstract - Class

The Herbert C. Bonner Bridge, constructed over Oregon Inlet for just $4 million in 1963 to connect the northern and southern Outer Banks, has lasted beyond the projected life of the project and must be replaced for safety reasons. Since it’s initial construction, it has cost the state over $56 million in repairs and maintenance, and the Inlet itself has continued to move southward threatening the southern end of the bridge. Without the current riprap and temporary jetty currently in place, the bridge would have failed long ago. In addition to the highly unstable inlet, the Pea Island National Seashore containing Highway 12 often overwashes causing road closures, and several recent breaches of the island have destroyed portions of the road resulting in construction of temporary bridges south of Oregon Inlet. We discuss the history of the original project, the continued maintenance issues, and the biological, social, and economic threats to the Outer Banks resulted from Bonner Bridge removal. We explore three viable alternatives, and make recommendations as to which option we believe will be best suited for long-term future of the Outer Banks.

Introduction (Taylor, Olivia, Brandi)

The North Carolina coastal zone is an arrangement of diverse structures that give it its unique layout (Riggs et al. 2008). A very pertinent part of North Carolina’s composition is the Outer Banks, an area of barrier islands located off the coast, extending roughly 320 kilometers (Inman et al. 1989). These islands are home to about 5,000 residents, serve as a sanctuary to various endangered species, and offer well-known beach communities. Because of this the Outer Banks provides a seasonal tourist spot for sightseers (Dean 2012). Attractions include lighthouses, historic sites, nature preserves, local businesses, and the beach itself. The Outer Banks are considered an important part of North Carolina’s coastal region historically, economically, and environmentally.

Unfortunately, the Outer Banks are threatened by coastal erosion. These barrier islands are not permanent and face constant change both gradually and rapidly. These fluctuations are due to numerous environmental factors such as wave erosion, storms, and continuous sea-level rise.
(Riggs et al. 2008). It is estimated that about 700,000 cubic yards of sand are moved along the Outer Banks shoreline each year (Dean 2012). Various methods have been implemented to try and slow this process. These methods include, but are not limited to, jetties, groins, dikes, and dredging (Pietrafesa et al. 2012). Despite these approaches, changes among the Outer Banks’ shores are inevitable. Because of this, the Outer Banks faces several pending issues, one of which is transportation to and from the islands. Currently, the main source of transportation is a bridge connecting Highway 12 to the mainland.

Table 1. The varying rate of sea level rise in northeastern north Carolina for the last 11,000 years (extracted from data in Horton et al., 2007, in press and Kemp et al., 2007).

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Sea Level Rise</th>
</tr>
</thead>
<tbody>
<tr>
<td>11,000 - 8,000 yrs ago</td>
<td>30 inches/100 yrs</td>
</tr>
<tr>
<td>8,000 - 2,100 yrs ago</td>
<td>6 inches/100 years</td>
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<tr>
<td>2,100 – 200 yrs ago (100 BC – 1800 AD)</td>
<td>3 inches/100 years</td>
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<tr>
<td>200 – 100 yrs ago (1800 AD – 1900 AD)</td>
<td>7 inches/100 years</td>
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<td>100 – 0 yrs ago (1900 AD – 2000 AD)</td>
<td>16 inches/100 years</td>
</tr>
</tbody>
</table>

The Herbert C. Bonner Bridge is a lifeline for the barrier island communities, connecting them to the Northern Outer Banks. It is informally known as Bonner Bridge, and was officially open to the public in 1963. It created a quick way for island residents and tourists to access the Hatteras Island beaches in minutes, rather than taking a lengthy ferry ride.

Up until 1846, Hatteras Island was connected to the Northern Outer banks, that is until a hurricane came through and created a deep inlet between them. At this time a privately owned ferry run by Captain Tillet began making daily trips to and from Hatteras Island. This continued until the 1920s, when state run ferries began taking over. This allowed residents, tourists and fishermen access to the island, and it also allowed for a new source of revenue for the residents. The ferries at the time were able to provide transportation to 2,000 people daily; however, they became extremely expensive, costing half a million dollars a year to maintain.

As a result, state and federal governments decided to build a 2.7-mile long bridge that would span the inlet. The bridge was estimated to cost about $4 million dollars to complete. The original contract for construction of the Bonner Bridge was awarded by NCDOT to McLean Contracting Company, Baltimore, MD on February 15, 1962. Construction of the bridge was completed on April 7, 1964 (Moore et al. 2008). Portions were paid for by the state, the federal government, the National Park Service, and North Carolina Congressman Herbert C. Bonner. Although it provided the means for a huge number of tourists to visit the island, in retrospect the engineers may not have adequately considered the treacherous weather that is prevalent in the area, and how it would affect the bridge’s longevity.
Since the construction of Bonner Bridge, in 1963, the bridge has had to consistently be maintained in order to keep it up and running for public use. The bridge continuously faces damage from salty air, turbulent waters, and ocean floor erosion (NCDOT, A). Occasionally, the bridge also receives damage, as does the rest of the Outer Banks, from coastal storms (Witcher 2012). Destruction repairs require both a team of structural engineers and deep sea divers to mend the damage (Outerbanks.com). The state has spent over $56 million on the bridge since 1990 in order to maintain it and complete repairs (NCDOT, A). These renovations occasionally cause the bridge to shut down, but are becoming more frequent with time. In addition, the projected costs continue to rise, as time persists. Because of this, it has become necessary to construct a new bridge.

While the historical bridge is still traversable, the bridge has, over the last couple of decades, shown significant structural problems, which has drawn the attention of many city officials called for immediate action (McCloskey, 2013). The notorious problem in regard to Bonner Bridge, or any bridge built in its place, is the fact that millions of dollars will be put into building an infrastructure on shifting sands. The erosion of the shoreline has an unforeseeable future; however, back in December of 2013 it did require the closure of Bonner Bridge for more emergency repairs (NCDOT, A). The aforementioned closure of Bonner Bridge called for short term closures to allow workers to aggressively dredge sand from the Oregon Inlet and place it around the bridge’s supporting columns (NCDOT, A). Related issues in the past were resolved by placing bundled rocks around the pilings in order to re-anchor the supports by collecting sand; however, this was not meant to be a permanent fix (Walker, 2013). One of the most longstanding impacts was when Hurricane Irene hit in 2011; the bridge was forced into closure for six plus weeks (Southern Environmental Law Center).

The aforementioned natural disaster that took place back in 2011 is just one of many that has impacted the Outer Banks and the man-built infrastructures, like the historic Bonner Bridge. When first built, the Bonner bridge was supposed to have a lifespan of thirty years, however, it is now fifty years old (Fuller, 2013).

The debate about what to do about Bonner Bridge has been going on since the late 1900s (Southern Environmental Law Center). Thus far the state has spent roughly $56 million on repairs since the alternatives were mentioned many years ago (Fuller, 2013). The two familiar alternatives that are being considered are the long bridge and the short bridge. The long bridge alternative was brought into existence in 2003 after the Secretary of Transportation considered the short bridge to be "no longer viable due to recent trends in shoreline erosion” (Lutz, 2006; Table 1). The long bridge was proposed to be 17.5 miles long and would span across the Pamlico Sound and spread to the northern tip of Hatteras Island (Figure 1). This alternative would completely bypass Pea Island National Wildlife Refuge and avoid various “hotspots” along N.C. Highway 12 where storm-wash is common (Southern Environmental Law Center). The short bridge alternative, which was recommended in 1993 and is still considered a viable option today, would be a 2.3-mile parallel bridge (Southern Environmental Law Center). The plan here was to place a bridge farther west of Bonner Bridge but make it parallel to it so that it could be realigned through N.C. 12 and the National Wildlife Refuge. The Southern Environmental Law Center (SELC) and the North Carolina Department of Transportation (NCDOT), as well as other law officials, are still in an ongoing debate about what should be done about Bonner Bridge.
Biological Considerations  (Travis, Haley, Amber)

Pea Island National Wildlife Refuge

When Pea Island National Wildlife Refuge was first established in 1937, it was a breeding ground for migratory waterfowl and many other species of wildlife (Matson and Carter, No Date). Pea Island is 13 miles long with over 6,000 acres of ocean beach, dunes, fresh and brackish water ponds, salt flats, and salt marsh (Refuge Watch, 2007). Pea Island alone is populated by thousands of migratory birds and other wildlife, some that are endangered (U. S. Fish and Wildlife Service). With its beautiful scenery and vast wildlife, Pea Island National Wildlife Refuge attracts 3 million visitors annually. Pea Island was also listed in the Defenders of Wildlife, “Refuges at Risk”, as one of the ten most endangered refuges (Refuge Watch, 2007). This is due to the threat of the Bonner Bridge replacement. The Herbert C. Bonner
Bridge was built over the Oregon Inlet to Pea Island where the Pea Island National Wildlife Refuge is located. The authority of new construction of a replacement bridge lies in the hands of the North Carolina Division of Transportation (NCDOT). Alongside NCDOT, the National Environmental Policy Act (NEPA) is working to find a solution that will benefit both the community and the Refuge (U. S. Fish and Wildlife Service).

NCDOT initially proposed four alternate routes for the construction of the new bridge (U. S. Fish and Wildlife Service). The first option is the shortest and cheapest bridge but it would have the greatest impact on the migratory bird habitat (Figure 1). The second option would land in the middle of the habitat but would greatly affect the submerged aquatic vegetation beds; and these are vital for commercially-valued fishery resources. The third option would have the bridge landing just south of the wildlife refuge but would have the most impact on the submerged aquatic vegetation beds. It is also the most expensive option due to the shallow-water construction, which is very costly. The fourth and final option (Figure 1) is the longest bridge, would also fall south of the habitat but would have the least impact on the submerged aquatic vegetation beds. Options two and three were eliminated by NCDOT because of the negative impact to the submerged vegetation and the high cost of shallow water construction (U. S. Fish and Wildlife Service).

With the elimination of two out of the four options that were proposed by NCDOT, they are now left to consider what is now viewed to be the heart of the discussion surrounding the issue of replacing the Bonner Bridge—short bridge or long bridge? This question is brought about due to the conservation of Pea Island National Wildlife Refuge (NWR), which is one of the last undeveloped barrier islands in the country. The short bridge solution would turn Pea Island NWR into a construction site, potentially harming the refuge and its inhabitants. The treatment of NC Highway 12 over the years has had many negative impacts on Pea Island refuge already. The erosion of parts of the island, as well as the artificial dunes has hurt the pristine habitat that the refuge contains. With constant beach erosion and severe weather, the ocean is moving ten to fifteen feet closer to highway NC 12 every year. This results in maintenance on the road and has a harmful effect on the wildlife and their habitat (U. S. Fish and Wildlife Service). Pea Island NWR has shrunk by a fifth of its size since it was established in 1937 due to these negative factors (Matson and Carter, No Date). The short bridge solution would run right through Pea Island damaging essential habitat for numerous species of migratory birds and other wildlife. The National Wildlife Refuge System Improvement Act helps protect refuges like Pea Island. With its passing in 1997, it now helps to protect refuges against such infrastructure as Bonner Bridge. For infrastructure to take place on these refuges, they have to be in agreement with the purpose, mission, and wildlife conservation of the refuge (Matson and Carter, No Date). The short bridge solution to Bonner Bridge does not follow the purpose and mission of Pea Island National Wildlife Refuge, according to the U.S. Fish and Wildlife Service. The 17-mile bridge proposal around Pea Island would conserve the habitat and wildlife there, but would obviously be significantly more expensive. With the long bridge going back into the Pamlico Sound, bypassing Pea Island, it would allow for restoration of the refuge due to constant roadwork of NC Highway 12, and the repairs of Bonner Bridge. According to the NCDOT, the state will spend up to $912 million by the year 2060 on maintenance of NC Highway 12, while continuing to disturb Pea Island in the process. The long bridge would eliminate these costs and would allow restoration of the refuge, from many years of constant maintenance work on the island (Refuge Watch, 2007). Pea Island, along with all of the Outer Banks is a constantly
changing and fragile place. With the decision of rebuilding of Bonner Bridge imminent, biological considerations should be considered in this process, including the conservation of Pea Island National Wildlife Refuge.

NCDOT wants to make the best choice that would be best for the community and for environment. While the shortest bridge would be the cheapest option, it has the most impact on the migratory birds and interferes with the “wildlife first” mission that protects the refuge. The long bridge would be the least harmful to the wildlife but it is also the most expensive option (U. S. Fish and Wildlife Service).

**Barrier Island is Continuously Changing in Size**

The barrier islands that make up the Outer Banks are continuously getting more narrow every year mostly due to natural causes (e.g., Table 1), but human impact can influence the decrease in growth as well (Smith et al. 2008). In one study, Pea Island and Avon-Buxton were two areas chosen to compare the different shoreline changes that have taken place over the past 146 years (Smith et al. 2008). By using geo-referenced aerial photographs and historic topographic and bathymetric surveys that dated back to 1852, the conclusion was made that processes that maintain the barrier island width such as flood tide transport, overwash and eolian processes have been disrupted over time by the development of roads and buildings along with coastal engineering that involves construction of barrier dune ridges, planted vegetation and artificial inlet closure (Smith et al. 2008). When these areas begin to grow narrower (or in some cases become more wide), they tend to “rebound” and set themselves back to order by natural causes. However, with the attempts to protect the barrier islands by constructing and maintaining artificial barrier dune ridges, it is causing opposite results to occur. Artificial barrier dune ridges along the Outer Banks have severely reduced the transport of sediment from the oceanic side of the island to the estuarine side, which causes the estuarine shoreline to recede (Smith et al. 2008). If the maintenance of these dune ridges continues, based on the rates of the narrowing of the barrier island that has been demonstrated throughout past years, one segment of Pea Island and the entire Avon-Buxton area will only survive as they are today for only 120-170 years at maximum due to rates of erosion. Figure 2 below was produced in the journal article, “Geospatial Analysis of Barrier Island Width of Two Segments of the Outer Banks”. Historic photographs were used to show the Avon-Buxton area continuously decreasing in size between the years of 1852 and 1998 due to overwash and erosion. The island greatly decreases in size every year and does not show any sign of growing in width.
Figure 2. Changes in width of North Carolina’s Outer Banks from 1852 to 1998 (Smith et al. 2008). Note that artificially-created and maintained dunes has limited sand transport from natural processes (overwash, etc.) from the ocean-side to the sound-side of the islands.

**Impacts of Dredging**

The biological impacts that will result from dredging will affect different organisms and ecosystems in the areas where the bridge is to be rebuilt. According to the U.S. Fish and Wildlife Service, some marine and estuarine organisms (especially those in the larval state) will be caught in the hydraulic dredge head, entrained into the pipe and then discharged on to the beach. There is also the possibility that sea turtles of smaller size could get caught in the hydraulic dredge as well (U.S. Fish and Wildlife Service 2013). Hopper dredges will steadily decrease the grain size while also increasing the amount of heavy, dark mineral content of the sand. This alternation of beach dynamics can result in sand temperature increasing from the dark minerals, which can affect the sex determination and incubation period for sea turtles (U.S. Fish and Wildlife Service 2013). This can also cause the sand to be more heavily compacted, which will lead to starvation of the mole crab (*Emerita*) and coquina (*Donax*), two critically important foodweb species of the intertidal zone. These organisms feed by swimming currents and then burrowing themselves in the substrate (Erftemeijer and Robin-Lewis 2006). If the sand is compacted, they will not be able to position themselves for feeding. Another effect of the heavier and darker sand material is that it can alter the physical beach characteristics to the point where it would not be suitable nesting habitat for federally listed sea turtles (Erftemeijer and Robin-Lewis 2006). Dredging has also been shown to have a lethal impact on bivalves such as mussels and oysters. Dredging causes high levels of suspended material, which can clog their feeding mechanisms due to the fact that they are filter feeders (Erftemeijer and Robin-Lewis 2006). Also, if there is a lot of suspended matter caused by dredging, it can also block a sufficient amount of light that is needed for seagrass plants, epiphytes, microphytobenthos and macroalgae to survive.

**Water Quality, Fish Habitats, and Animal Communities**

Released in the NCDOT Bonner Bridge Replacement statement of Final Environmental Impact, any bridge replacement that occurs will result in constructional-related changes in the topography and soils (NCDOT 2005). Although this disturbance will only be temporary, water
quality impact will be a direct result of construction barge traffic, fill and pile replacement, and construction channel dredging. These will also cause a temporary increase in turbidity and have the potential to decrease dissolved oxygen levels. Decreased oxygen levels will affect the plankton distribution in that area of water and also the fish distribution as well. Construction of the bridge will disturb fish and shellfish resources by pile placement and by construction channel dredging (NCDOT 2005). The majority of the impact to fish habitats will be temporary and localized with the bridge construction (which will cause increased turbidity, noise and siltation) (NCDOT 2005). Permanent loss of alteration of fish habitats will result from the direct effect of shading water areas and pile placement. NCDOT also concluded that clearing within the construction area would either eliminate or displace most of the biota. These activities would mostly affect animal communities that are less mobile like small mammals, reptiles and amphibians—these will be lost with the removal of their habitat. However, the more mobile animals (large mammals and birds) will be better able to move out of the area of impact and will not be as greatly affected.

Social Considerations - Meganne, Cory, Adrian

Island communities require a lot of incoming transportation of goods to allow for a healthy social structure. Unless they are large enough or well-funded enough to have means to supply for the needs of the Island within the community itself, many of these programs are enabled by a connection, at least in part, to the mainland. Within a community, the disposal of garbage, the creation and stability of jobs, the supplying of electricity, and the support of industries, rely heavily on the ‘to and fro’ interaction between the island and the mainland. Hatteras Island and Oregon Inlet are no different. The connection of this area to the mainland is performed via the Bonner Bridge (Dean, 2012). This bridge provides not only transport to and from the island, but also gives the island certain necessities. These necessities include but are not limited to several different types of things. A good example of the service that this bridge provides for the islanders is the ability to fill and expand workforce opportunities. Laborers that work on the island but live in a different location must use the bridge to get to and from home and work in order to maintain their lives. This is a two-way street, as people who live on the island also may have jobs that require the use of the bridge as a reliable and fast path for commuting. The bridge also provides a reliable non-generator means of receiving electricity (Fox, 2013). A fast and effective evacuation route, this bridge is crucial for the areas it connects, as it provides more than just a road, as it also enables the islander way of life to be a much more convenient one. This bridge is much more than just a road.

Bonner Bridge is important to the social infrastructure of the Hatteras Island area. The Outer Banks Chamber of Commerce issued a statement via Chamber representative, Robin Mann, that stated, “We (The Chamber of Commerce) support the short bridge alternative, believing it is the only fiscally responsible and viable option.” In this statement released to the public over the Bonner Bridge controversy, Mann continues on, saying “The timely construction of this bridge is vital to maintaining safe, efficient, and reliable access and egress to and from Hatteras Island and Ocracoke Island.” In response to the effect that a collapse of the bridge would have, the statement goes on to state “…it will have a devastating economic effect, not only on Hatteras and Ocracoke islands, but also to all of Dare County, northeastern North Carolina, and eventually the whole State. It (The Bridge) is important to maintaining the
economic and social health, public safety, business, commerce, tourism and quality of life of residents of Hatteras and Ocracoke Islands” (Mann, 2012).

As evident from this excerpt from the Chamber’s Ms. Mann, public health, safety, and social stability rely on the Bonner Bridge to provide the lifeline to the residents and tourists of the island. It also provides the means of transporting things like garbage off of the island. The Chamber of Commerce website for Dare County describes the garbage as being transported off of the islands by the state and taken on trucks to the dump sites located on the mainland. The bridge provides quick and easy transport of the noxious garbage, with minimal people subjected to the smell (Outerbankschamber.com, 2012).

The bridge is also important, not only as a means of transport, but also as a source of electrical power (Fox, 2013). The Bonner Bridge is a main lifeline from main land North Carolina to Hatteras Island, which has, several small villages and over 5000 permanent residents across the island. Aside from just being a connection to the main land it is the island’s main source of electricity. “A 115-kV bridge cable rides in three conduits suspended from the Herbert C. Bonner Bridge deck. Because of weather conditions and salt contamination, the island has one of the nation’s highest electrical outage rates” (Bauer, et al. 1995). The cable was put into service on May 1, 1995 and to this day has been providing power to the people of Hatteras Island.

Replacement of the Bonner Bridge with a bridge running parallel to the pathway of the Bonner Bridge, or construction of the “Long Bridge” the same system could be applied, but an alternate source of replacement to the bridge (i.e., ferry), an alternate source of electricity to the island would have to be put into place. Another option that has been brought up is running a submarine cable, but in the research done by NCEMC a submarine cable is not possible. “The strong inlet currents, channel dredging operational concerns, the impact on marine life and the difficulty of future circuit repairs rule out placing submarine cable across the Oregon Inlet” (Bauer, et al, 1995). Permanent generators were replaced by the cable ran through the bridge because they did not provide the whole island with a sufficient amount of power. If the decision of a ferry is made, then research will be needed to identify a cheap and effective way of providing electricity to Hatteras Island.

Generators exist for the island to maintain power during bridge outages, but they are not a reliable steady source of electricity.

The rebuilding of Bonner Bridge faces many political hurdles. Due to the lawsuit brought by the Southern Environmental Law Center (SELC), construction of a parallel bridge running alongside the current bridge has been put on hold. The Case brought up by SELC revolves around the new bridge’s proposed path…which runs through part of the Pea Island National Wildlife Refuge (OuterBanks.com, 2011). The building of the bridge in this protected area directly would violate the legislation passed in 1937, which declared that Pea Island and its associated land was protected from development (Obtf.com A, 2009). The long bridge project was created to avoid endangering the Pea Island Wildlife Refuge, and makes it much easier politically to get the bridge built. The long bridge will have a very hefty price tag on it, and it has been quoted for pricing several times, and the estimates keep increasing, as more research is done into the necessary maintenance fees. Politically and socially that would mean a significant increase in taxes for N.C. residents (Refuge Watch, 2007). The long bridge would take much longer to enact, and the likelihood of the Bonner Bridge going permanently out in that time is quite high. (NCDOT A, 2012) While the proposed 17 mile bridge would make for a longer
commute for the residents, it is by far socially friendlier than the other main option of Ferry Systems (Midgett 2013). Currently, an emergency ferry system is in place during bridge outages, and that has provided a significant amount of disapproval from the Island’s 5,000 residents (Raleigh News and Observer, 2013). With the local opinion of the ferry system in mind, the ferry alternative has not been met with overwhelming enthusiasm. The cost of the ferry system would not be cheap, and it would require the use of diesel boats, putting out pollution (Corbitt and Farrell, 2002). Socially, the ferry system time wise can be unreliable. Residents going to and from their jobs would have trouble keeping track of the time schedule, as the channels are constantly changing, and therefore the routes have to change as well (Inman and Dolan, 1989).

If a permanent ferry system was to be used, there would have to be serious allowances made to the evacuation plans that govern the island residents. A social consideration that must be considered is how having the bridge or not having it (the bridge) will affect evacuation from the island. Bonner Bridge is the primary means for emergency evacuation as well as the primary route for EMS, fire service and law enforcement vehicles. With the absence of the bridge the backup plan of evacuation would be the ferries, which can only carry under 1,000 cars a day and depends on the weather conditions (Midgett, 2014). This would be an obstacle if the alternative to Bonner Bridge was to be a ferry system. Bonner Bridge is such an essential part of transportation for locals not only for emergency situations, but also for daily life so a decision on Bonner Bridge needs to be made soon. Something to consider when deciding whether to build a replacement bridge or whether to just get rid of Bonner Bridge is the cost of living. The estimated median household income in 2009 for Dare County was $47,270 as opposed to the state average of $43,674. The cost of living in Dare is higher than not only the state average, but higher than the national average. (Onboard Informatics, 2012) With the cost of living so high the question must be asked, how would not having Bonner Bridge affect the cost of living?

An alternative to the replacement bridge is a ferry system. Staten Island already has a successful ferry system that has lasted for decades. The Staten Island Ferry cost taxpayers $4.86 per passenger, each way. This adds up to an annual budget of about $108 million towards the ferry budget. For many Staten Islanders, the ferry is their primary means of transportation among locals (Paulsen, 2013). If a similar ferry system were to be implemented in North Carolina this would help pay off the costs of getting the ferries and in time the ferries, could also be the primary means of transportation for the locals.

Socially and politically, there is much to consider not only with the parallel bridge, but also with the proposed alternatives. There will be a large political and social upheaval if the Bonner Bridge is not replaced with a similar bridge or an alternative that provides the same necessities that the bridge allows. The island would not just be hit with an economic toll in face of the loss of the bridge, but moreover, a toll that would negatively impact the island as a whole, with one of the many facets of that impact being the sudden and inevitable instability of the economy. The working population that resides on the island but works off the island would be severely impacted, not only affecting the residents of the island, but also impacting the workforce that lives off the island and commutes to the island daily for work. That would obviously have an impact on the economic status of the island, but much less obviously, on the standard of living for the population.

Without a bridge replacement there would also be direct impact to such wide spread industries, like that of commercial fishing, a key industry in the Outer Banks. Commercial
fishing not just a long tradition on Hatteras Island, it is also a way of life for many people. Fishing is a tradition has been passed down from generation to generation, but in recent years the commercial fishing industry has been in a decline and many people all along the Outer Banks have lost their family businesses. In 2007 “North Carolina fishermen brought in a total catch worth more than 70 million dollars, according to the Department of Marine Fisheries. But the fish houses that buy and ship that bounty are rapidly disappearing from the coast. A study found that between 2000 and 2006, North Carolina lost a third of its fish houses” (Williams, 2007). Not taking into account bad years with small catches, many commercial fishing businesses and fish houses have closed down because of the hidden fees found in the fishing industry. Some of the largest fees are repairs to the boat and equipment, fuel and bait, and transportation of the fish to market. The most cheap and efficient way to ship fish is using a tractor-trailer truck, which is what fish houses have done for years in North Carolina. “In the 1960s-1970s, the peak of the commercial fishing industry in eastern North Carolina, every fish house (and there were more than two dozen east of Beaufort alone) owned its own fleet of tractor-trailer trucks that would take there fish as far north as New York’s fish markets” (Earley and Amspacher, 2008). Replacing the Bonner Bridge with ferries will put a new strain on the fishing industry. Perhaps they will have to purchase a new boat to take their catch to the mainland where it would have to be picked up by the distributor. Smaller cargo trucks would be alllowed on ferries, but not all fish houses use small cargo trucks. One other option used in Alaska is shipping the catch by plane, which has even more cost. On the Outer Banks, the only airport is the Billy Mitchell Airport. This is a problem that should be addressed while taking into consideration the replacement of the Herbert C. Bonner Bridge.

The bridge is crucial to the stability and sustainability of the population of Hatteras Island, and as such an equal means of travel on and off the island must be provided to attend to the needs of the 5,000 permanent residents and the swells of 55,000 visitors of the Hatteras Island/Oregon Inlet area.

Economic Considerations (Andrew, Nina, Zaneta, Takeisha)

Economic considerations concerning the Bonner Bridge will play a crucial role in North Carolina’s final decision regarding transportation on the Outer Banks. To the residents of the southern Outer Banks, tourists, and especially the government, the financial implications of rebuilding or replacing the bridge are most important.

The Bonner Bridge originally cost $4 million to build and services about 14,000 trips per day during peak times. The federal government invested $2.5 million into the bridge project while the state had to pay the remaining portion (U.S. Fish and Wildlife, 2010). At the time of construction, the environmental impact on the bridge and road was not fully understood and now, due to constant beach erosion and severe weather, over $50 million has been spent to protect the Bonner Bridge and NC 12 from the ocean (U.S. Fish and Wildlife, 2010). Another $2 million in required repair work is scheduled to begin this fall (NCDOT A).

The Federal Highway Administration has approved the plan to replace the bridge over Oregon Inlet that connects with Pea Island and lies within the Cape Hatteras National Seashore. The final alignment of the bridge has been a point of contention. A longer alignment, which curved farther inland, was estimated to cost close to $900 million (Breen 2010). This bridge option was not selected. On July 26, 2011, NCDOT awarded a $215.8 million contract to replace the bridge with a much shorter option (NCDOT A). Construction was set to begin in early 2013
but was halted once again after an appeal was filed by the SELC. The new bridge was scheduled to open to traffic in spring 2015 with the majority of the existing bridge demolished by 2016 (a portion will remain as a fishing pier), but new lawsuits have pushed that timetable back significantly (Outerbanks.com, No date).

Financially, the up-front cost of building a long bridge, short bridge, or introducing a ferry system needs to be considered first (Table 2). Recently the Bonner Bridge was deemed unsafe after vast amounts of sand that supports the structure had been washed away by the strong currents and tides that rip through the Oregon inlet. Because of this the NCDOT has been spending hundreds of thousands of dollars to continually dredge the channel and pump sand onto the bridge support pilings. Recently the NCDOT awarded $1.6 million to the construction company, Carolina Bridge, to help maintain the current bridge while the new bridge is being built (Walker 2013).

Table 2. The costs, life span, and projected maintenance costs associated with the three viable alternatives based on previous estimates described in the text (current study).

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<th>Lifespan</th>
<th>Maintenance Cost</th>
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<td>~55 Years</td>
<td>$230 Million Through 2060</td>
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<td>Long Bridge</td>
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</tbody>
</table>

The secondary economic impacts also need to be considered when dealing with this issue. In early December the Bonner Bridge was shut down for almost two weeks. During this period it was estimated that the 8 villages of the Southern Outer Banks lost over $110,000 per day, and this was during the off season. If the bridge was deemed unsafe during peak summer months the loss in revenue would be up to $3.6 million per day (Kurry 2013). If a sudden disaster happened and the current Bonner Bridge was compromised, the lost revenue could add up to the cost of replacing the bridge entirely.

Although the short bridge gives NC a cheap and immediate option, it is expected that the new bridge will need to be replaced sometime within the next 75 years, which will cost another couple hundred million, and who knows if the inlet will still be where it is by then. It does not make much sense to build an identical bridge to a current bridge with a design has been proven to be less than efficient. However something does need to be done immediately to prevent the closure of the Bonner bridge during peak summer months.

Another economic consideration that needs to be addressed is how all of the options could affect tourism, the Outer Banks’ number one industry. If the short bridge was built in time there would be little to no impact on tourism. Vacationers and residents would be able to safely
use the current Bonner Bridge until the new bridge was completed with little negative impact. The same goes for a long bridge; it is likely that the current section of highway 12 and Bonner Bridge could be used until the long bridge was completed. The only difference between the two bridges would be that it would take much longer to complete the long bridge so NC would have to continue to spend money in order to maintain the current bridge for a longer period of time. The only option that will likely affect Outer Banks tourism is the ferry system, and it could have either positive or negative effects. On one hand people might think of the ferry system as a hassle because of the long process and price of a ticket. If this were the case, less people would travel to the Southern Outer Banks, which would financially impact restaurants, realties, tourist attractions, and mom and pop shops perhaps not to the point where the whole island would go bankrupt but it is likely some businesses would go out of business. On the other hand, the lure and excitement of a ferry ride may intrigue some, causing more people to travel to the Southern Outer Banks, stimulating the economy. To observe what it might be like if the Southern Outer Banks were only accessible by ferry one could look to Ocracoke Island, which itself is only accessible by ferry. Ocracoke is far less developed than the rest of the outer banks and it may be because it is only accessible by ferry. Further financial implications of a ferry system would be the cost of waste disposal and transport of resources.

The dollar impact of corrosion on highway bridges is considerable. The annual direct cost of corrosion for highway bridges is estimated to be $6.43 billion to $10.15 billion, consisting of $3.79 billion to replace structurally deficient bridges over the next 10 years, $1.07 billion to $2.93 billion for maintenance and cost of capital for concrete bridge decks, $1.07 billion to $2.93 billion for maintenance and cost of capital for concrete substructures and superstructures (minus decks), and $5.0 billion for the maintenance painting cost for steel bridges. This gives an average annual cost of corrosion of $8.29 billion. Life-cycle analysis estimates indirect costs to the user due to traffic delays and lost productivity at more than 10 times the direct cost of corrosion (Yunovich, No date).

Every bridge in North Carolina is inspected at least every two years in accordance with the National Federal Standard for Bridge Inspection. Structural problems identified during inspections are addressed by NCDOT bridge maintenance crews or through contract repairs. NCDOT distributes $12 million annually for bridge inspections. NCDOT has a budget, which includes $65 million annually for bridge maintenance. The department’s 2009-2015 State Transportation Improvement Program includes $1 billion to replace 838 bridges across the state. To be eligible for this federal bridge replacement funding, bridges must have a sufficiency rating of less than 50 (NCDOT D).

NCDOT completed its latest repair project for the Bonner Bridge on May 9, 2012. This included repairing the steel and painting three of the main spans of the Bonner Bridge over the main channel. In early November 2011, crews completed a $3.2 million scour protection project to prevent the sand around the bridge’s support structures from eroding due to the flow of water through the inlet. Devices called A-Jacks were installed around 20 of the bridges piles. A-Jacks help keep the existing sand in place, and also slow the water down, which helps sand fall down onto the floor of the inlet around the piles (NCDOT B).

The NCDOT currently maintains about 13,500 bridges across North Carolina, ranking our state as 13th in the nation for highest number of state-maintained bridges. A state funded NCDOT Bridge Improvement Program was put into place and successfully met the legislative
initiative to commit approximately $450 million in state funds for bridge improvement programs. Right now this plan is affecting approximately 1,200 of North Carolina’s bridges (NCDOT C).

As stated above NCDOT annual budget for bridge maintenance is $65 million and $12 million annually for inspections. Together that’s $77 million a year. Comparing that to the $56 million already spent on inspecting and maintaining the Bonner Bridge since 1990, that’s about only 1.273% of the annual budget. The Improvement Program gives $1 Billion to replace 838 bridges. If we were to divide that evenly that would amount to roughly $1,193,317.42 to replace each bridge. Now comparing that the construction of the long bridge option which would cost $1.2 billion alone, or even the short bridge option, which would cost $191 million, is clearly out of the budget of the program. A lot of time, money, and work has been put into this bridge, but when the numbers are laid out, the amount of money put into this could be used elsewhere.

**Exploring Alternative Solutions: Implementing a Ferry System to Replace Bonner Bridge: An Economic Analysis Based on Case Studies**

The Herbert C. Bonner Bridge is a structure spanning the length of the Oregon Inlet which connects Dare County to Hatteras Island. This structure, built in 1963, originally had an estimated lifespan of 30 years and thus has already stood sixteen years beyond its intended duty (Citizens Action Committee, 2013). A long standing debate over the replacement of the bridge has focused primarily on installing a new structure in the same place as the current bridge, or constructing a new, seventeen mile bridge that could cost upwards of $1 billion (McCloskey 2013). What seems to have received little attention and research is the possibility of a third option: the implementation of a high-speed ferry system, which could transport thousands of people per day. Here, we will provide brief background information for several existing ferry systems and use them as potential examples for the infrastructure of a new branch of the ferry system in North Carolina.

**The Staten Island Ferry**

Since the early 1900s, the New York City Department of Transportation has provided a ferry system spanning 5.2 miles to connect Manhattan to Staten Island (NYC DOT, 2013). Today, the ferry transports 60,000 passengers on weekdays (a number that increases on the weekends), for a total of 20 million people per year, and serves as the only non-vehicular mode of transportation between Manhattan and Staten Island. In 2005, the New York City Department of Transportation purchased three new high-efficiency ferries built by the Manitowoc Marine Group. These ferries, costing $40 million each, have the capacity to carry 4,440 passengers and 30 vehicles per trip (SI Ferry). The Staten Island Ferry is free to ride, however, the ferry actually costs $4.86 per passenger per trip in tax payer dollars (Paulsen 2013).

**High Speed Commuter Ferries, Seattle**

The Washington State Ferry System is the largest ferry system in the United States, with 10 routes and 22 vessels, and serves 22 million people annually (WSDOT 2014). Seattle, Washington runs several ferries for commuters spanning a 13.7 nautical mile stretch, with a running time of 40 minutes and can carry up to 250 passengers (at $7.00 each) per trip. Between the years 2007-2009 the cost for maintaining one ferry running between Vashon, Washington and Seattle cost $3.5-$4.8 million (Berk and Associates 2004). According to that same report, the initial cost of the start-up for new vessels is seen in Table 3.
**British Columbia PacifiCat Fleet**

In the late 1990s and early 2000s, British Columbia planned to implement three high-speed ferries for transport through Vancouver, BC. Although the total plan never came to completion, three high-speed passenger ferries were constructed by BC Ferries in British Columbia. Each vessel could travel at a speed of 34 knots (39 miles per hour), and carry 1,000 passengers and crew along with 250 vehicles. The cost of the three vessels (combined) totaled $463 million, a price that nearly doubled the original quote (Associated Press, 2000).

**Bringing the Fleet to North Carolina**

The North Carolina Department of Transportation currently runs 24 ferries throughout the state, including an emergency ferry route that is already established to cross the Oregon Inlet in the event of a natural disaster, or the Bonner Bridge forcibly being shut down (Boyer 2014). In the 1950s, North Carolina ran ferries across Oregon Inlet that could carry up to 2,000 passengers daily, but cost nearly $500,000 per year, which was too much for the state to afford. To resolve this problem, the government of NC, subsidized by the federal government, installed the $4 million Bonner Bridge (Boyer 2013). The Bonner Bridge has since cost the state millions of dollars to maintain, costing $50 million between the years of 1987-1999, with another $2 million in repairs budgeted to begin in the fall of 2013 (Boyer 2013, McClosky 2013).

The Bonner Bridge has reached the end of its lifespan, and considerations for a replacement have been discussed for several years. Two main options stand today for the replacement of the now deteriorating Bonner Bridge. The first is a $216 million project in which a new bridge will replace the existing bridge in its exact location (Midgett, 2014). Due to an overwhelming backlash from environmental groups, the government of NC has been forced to seriously consider the construction of a 17-mile, $1 billion bridge crossing the Pamlico Sound and bypassing much of the venerable highway 12. Jim Trogden, chief operating officer of the NCDOT, has been quoted as saying “The long bridge would be the single most expensive bridge built in the U.S. to date and the second longest bridge on Earth. North Carolina could never afford it (the long bridge) in any reasonable scenario, because there is an existing right-of-way.” Although many hold this sentiment, the construction of the 17 mi “long bridge” is still being considered as a viable alternative to the existing route.

What has not garnered enough consideration is the economic benefits of re-instating a ferry system within this region of North Carolina. Although the existing ferry system is not adequate to support tourism industry along Hatteras Island, a new ferry system could be

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**Table 3:** 2004 estimates for the start-up cost of new ferries in Washington State.

<table>
<thead>
<tr>
<th>No. of passengers</th>
<th>Purchase new</th>
<th>Purchase used</th>
</tr>
</thead>
<tbody>
<tr>
<td>149</td>
<td>$5 million</td>
<td>$2 million</td>
</tr>
<tr>
<td>250</td>
<td>$9 million</td>
<td>$3.6 million</td>
</tr>
<tr>
<td>350</td>
<td>$11 million</td>
<td>$4.4 million</td>
</tr>
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implemented within the cost of the current budget for the replacement of the Bonner Bridge. Hatteras Island is home to approximately 5,000 year-round residents, and draws nearly one million visitors each year. It is crucial that transportation to and from the island can support a high volume of patrons, so using existing high-efficiency ferry systems as a model is key.

A new high-speed ferry connecting Hatteras Island to the rest of civilization could be constructed to service one of three routes (Figure 3). The fastest route would be the 2mi stretch that connects both ends of the Oregon Inlet, where the Bonner Bridge currently exists. If ferries such as the ones purchased in 2005 for Staten Island are used, the ferry could cross this stretch in approximately 15 minutes. Option B is a 10 mi trip, which could take around a half hour in one direction with the high-speed vessels. Option C, spanning 17 mi and taking just over an hour, would connect Hatteras Island directly to the mainland, saving commuters from the nearly 2 hour trip that they currently must travel if they intend to reach the mainland by car.

![Figure 3: Potential ferry routes. Option A (2mi) would run along the existing route of the Bonner Bridge, Option B (10mi) would run from Wanchese to Hatteras Island and Option C (17mi) would connect Hatteras Island to the mainland from Manns Harbor.](image)

If North Carolina chose to purchase new high speed ferries such as the ones purchased in Staten Island, Seattle or British Columbia rather than implementing either of the new bridges, the state could save money. If the state purchased one high speed ferry, costing anywhere from $40-$100 million, it could still have (at minimum) another $1 million to construct landing terminals for the ferry, and carry an adequate amount of passengers per trip. Furthermore, by charging passengers for each trip and potentially for parking, the state could start to make their money back, eventually earning enough back that new ferries could be added to the fleet. Another consideration for the funding of a ferry system would be to enlist the financial aid of private
investors. Such funding has been successful before, and would reduce the financial debt taken on by the state.

**Alternatives** (Amanda, Brenna, Dustin)

Bonner Bridge was constructed by North Carolina Department of Transportation in 1963 for $4.1 million. The state of North Carolina contributed approximately $1.5 million and the federal government paid $2.5 million (NCDOT A). The bridge extended N.C. Highway 12 over Oregon Inlet, thereby “permanently” connecting Hatteras Island to the bottom of the Outer Banks (McCloskey, 2013). Since 1990, NCDOT has paid over $56 million in repairs, with another $2 million underway (NCDOT A). Engineers have determined that by 2016 the bridge will no longer be structurally sound enough to allow commuters (Midgett 2014). Two general replacement structures have been proposed: a $215 million bridge parallel Bonner Bridge, or a $930 million bridge running 17 miles through the Pamlico Sound (Kozak, 2013).

One alternative that has been proposed to either bridge is a ferry system to service Hatteras Island. Hatteras has 5000 permanent residents, 35,000 summer workers, and 2.5 million annual visitors (Midgett 2014). There are economical, environmental, and sociological advantages and disadvantages to a ferry system.

Currently the North Carolina Department of Transportation Ferry Division has 22 boats that operate on seven routes (Tsai et al, 2011). A 1991 feasibility study by NC explored replacing Bonner Bridge by expanding the current NCDOT Ferry System. At that time, 12 Hatteras Class ferries were proposed for a 3-mile route between Bodie and Hatteras Island (Colwell et al, 2013). These low speed vessels have a 30-car capacity and are designed to run in inlet waterways. These vessels are smaller and cheaper than both River and Sound Class Ferries, with River class ferries costing $15 million. The forty-year cost of the system was estimated at $418 million, and was deemed unfeasible (NCDOT A).

In 2011, an 18-mile route bypassing Pea Island was researched and also deemed unfeasible. To accommodate daily traffic use of Bonner Bridge, a total of 38 River Class Ferries were needed to expand the current Bodie Island to Rondanthe ferry route. The 50-year cost was estimated at $6 billion (Tsai et al, 2011).

Recent advances have reduced costs of high-speed low-draft ferries. In a study in 2011 examined a low draft high-speed ferry operating in the islands around Spain. The Austal Avenmar Dos vessel had a draft of 7.8ft, 150-vehicle capacity, traveled at 40 miles per an hour, and had a cost of $9 million. With the increased speed and vehicle capacity, fewer boats and a crew would be required to expand the Bodie Island to Rondanthe ferry route (Tsai et al, 2011).

In 2003 the New York City Department of Transportation purchased three ferries at $40 million each, with a 4440 passenger and 30 vehicle capacities. With a draft of 14 feet, these ferries service a five-mile route in 25 minutes (NYCDOT 2013). All three ferries were constructed by Manitowoc Marine Group and feature “hurricane safety features.” If a similar system was implemented in the Oregon Inlet, four ferries with an initial cost of $160 million on the vessels alone, running from 6am to 9pm every 30 minutes could carry 1800 cars to the island and approximately 500,000 people. Currently the Bonner Bridge sees over 2 million cars a year, and this system could handle 600,000 vehicles running 365 days of the year (Breen 2010). Other costs such as terminal construction, ferry maintenance, and staffing would have to be accounted
for. NYCDOT does not charge a toll and sees over 2 million passengers a year on average (NYCDOT 2014). If a $5 toll were charged over $10 million would be generated. Similarly, tolls would be a viable source of revenue to offset the cost of expanding NCDOT ferry system in the Oregon Inlet.

Although there are operating ferry systems in the Outer Banks of North Carolina, ferries still impose environmental concerns. In order to have a ferry system that runs to and from the current location of Bonner Bridge, the Oregon Inlet would need to be dredged constantly. This is because the inlet is too shallow and constantly changing and cannot support the current ferry system without adjustment. The average depth of Pamlico Sound is relatively shallow and is about 5’-6’ feet (Pamlico Sound). Webster’s dictionary defines the act of dredging as “to deepen (as a waterway) with a dredging machine”. The dredging causes a loss of sediments to the sea floor, a loss of material during transport to the surface, and overflow from the dredger as well as material loss from the pipelines during transport. On the other hand, dredging can be positive and help the environment. These positives include removing contaminated sediments from the sea floor and improving water quality which is made possible due to water depth and flow. More importantly, the dredging helps sand depletion from the shore line due to erosion and sea level rising, which could ultimately help save the Outer Banks (UK Marine SACs Project). Another positive aspect the ferry system would bring to the Outer Bank’s environment is that it would not affect the National Wildlife Refuge. The refuge is located on Pea Island, the ecosystem depends on the wash over of sand, which builds up marshes in the Pamlico Sound. The dredging could help build up the marshes in the Pamlico Sound, which would help restore the natural habitat for migratory birds, sea turtles, and other species (Build The Long Bridge Coalition).

Furthermore, from an environmental aspect only, the reduced car and foot traffic would be beneficial to Pea Island Wildlife Refuge. Off the coast of California, the Catalina Island strictly limits the number of vehicles allowed on the island and promotes alternative forms of transportation such as golf carts, bicycles, and walking. Tourism is still a viable source of income for the island (Catalina Island Chamber of Commerce & Visitors Bureau, No Date). If Hatteras Island were to expand its ferry system and couple it with these alternative forms of transportation, the island could still sustain large number of mobile tourist while having a reduced carbon footprint.

As a possible alternative, expanding the current ferry system does have disadvantages. Having a ferry system may sound like the best alternative because then there is not the worry of maintaining a bridge that is safe enough to drive over year round but there are other considerations. The tides are constantly changing on the Outer Banks and that poses a problem for the shoreline when it comes to bridge construction. Orrin Pilkey, a retired Duke professor, said that “Given projected sea level rise, accelerating coastal erosion and expected increase in storm intensity, the best long-term solution and best public investment for transportation to Hatteras Island is a modern, high-speed, high-capacity ferry system” (Pilkey, 2014). While there are ferries that can sustain hurricanes, the ferries that are currently in the Oregon Inlet cannot. Even larger and faster ferries that can carry more vehicles and passengers may not be a safer alternative. In Catherine Kozak’s article titled ‘DOT Torpedoes Ferries at Oregon Inlet’ she states that “no high-speed ferry exists today that could safely carry millions of vehicles a year across the heavily shoaled Oregon Inlet and Pamlico Sound” (Kozak, 2013). There have been successful uses of high-speed ferries used overseas for passenger and vehicular traffic, but those ferries have drafts that are too deep to run safely in the Oregon Inlet. The waters in the Oregon
Inlet are constantly changing the channels, even over a time span of a few hours. Jed Dixon, the state Ferry Division deputy director said, “It is not safe when you’re running that kind of speed—40 knots, because if it runs aground you’re talking major damage, potentially to the hull” (Kozak, 2013). In order to have a larger and faster vessel to get across the inlet the vessels would need to skim the top of the water to avoid hitting the bottom. Hovercrafts and Catamarans can skim the water surface and carry 80 vehicles while traveling at 50 mph, but if any of these vessels were to be damaged there is not an off site maintenance facility, and those high speeds could potentially be hazardous in the Outer Banks conditions (Kozak, 2013). Another safety concern is for emergency personnel. If there is an emergency on the island, for instance if a resident needs to be taken to the hospital, ferry time would considerably lengthen the response time for responders, especially if weather conditions were not ideal (Midgett, 2014). Both of the islands’ power is ran underneath Bonner Bridge, if something were to happen to the bridge the islands could lose power, causing an even greater safety concern for residents and visitors (Midgett, 2014). If the islands lost power during a storm they could be in even more trouble if they did not have a bridge to evacuate and had to rely on ferries.

Without a bridge or a highway a mass evacuation off of the Outer Banks would be difficult. The emergency ferry system can only hold less than 1,000 cars per day and that is only in ideal weather conditions (Midgett, 2014). If weather took a turn for the worse it could be more dangerous to evacuate using the ferries and be in open water than to just remain on the island. However, if people were stranded on the island due to inclement weather, there are currently no emergency shelters set up on either Hatteras or Ocracoke (Midgett, 2014). This poses an entirely new concern; not only would people be stranded but they would not be able to get immediate help if it became necessary. Even on days when the weather is good, ferry use can become difficult, for instance, when fog rolls in. If the fog is too thick the captain can not see and to avoid risk of hitting land they have to sail even slower, or sometimes “stop in transit and idle” said Clay Harris, ferry division’s chief engineer at Hatteras (Kozak, 2010). Even if winds exceeded 35 mph the Hatteras ferries could not operate in the 6.5 mile channel (Kozak, 2010). It would not necessarily take a whole lot of bad weather to make a long ferry ride even longer due to unforeseen circumstances.

The drive over the Bonner Bridge is easily done in a day without wasting a full day of vacation or spending an entire day running errands. However, what should be a 30-40 minute drive can easily take 2 and ¼ hours on a ferry (Hampton, 2013). With that being said, the ferries still are the transport for thousands, if not millions of visitors who wish to travel to the Outer Banks (Outerbanks.com, No date B). Bonner Bridge holds 5,200 cars and trucks a day while the Stumpy Point ferry between Hatteras and the mainland can only do about 760 a day (Siceloff, 2013). The limited number of spaces on the ferries means people have to wait for a ride in hopes that they even get on that day. Residents and tourists have to wait in the same line for a spot on the ferry, leaving tourists stranded on the island, and residents unable to get to the mainland for errands (Kozak, 2010). While spaces are limited, there are still a handful of people that would like to resort back to the original ferry system and just let the bridge deteriorate. However, “after decades of operation, the North Carolina Department of Transportation (NCDOT) has ferry operations down to a science, with daily operations that rarely skip a beat, and hundreds of trips occurring every day throughout seven coastal North Carolina routes” (Outerbanks.com, No date B). Permanent ferry docks would need to be set up, but with the number of vacationers, and limited space, this is not a practical solution (Outerbanks.com, No date A). The current NC Ferry
System operates three classes of ferries that are used in specific routes depending on the time of travel, how many vehicles frequent the route, and how shallow the body of water is (Outerbanks.com, No date B). The different ferry options are out there depending on what is needed at each location. Going to and from the Outer Banks is popular for tourists and locals, and with the limited amount of space a ferry has and the length of time the trip takes, many wonder if implementing permanent ferries would be a viable solution.

Figure 4. A different design from the current multiple pillar design of the current Bonner Bridge, which perhaps should be considered as less intrusive on the inlet itself.  
http://physics10bcore.wikispaces.com/Cable-stayed+Bridge

Another bridge option, which has not been evaluated to fit the Outer Banks, would be building a cable-stayed bridge. A cable-stayed bridge is defined as a bridge in which the weight of the deck is supported by a number of cables running directly to one or more towers. The idea for cable-stayed bridges first appeared in a book called Machinae Novae that was published in 1595; however, it was not until this century that engineers began to use them. The design is perfect for rebuilding bridges that still have standing foundations. These cable-stayed bridges require less cable than suspension bridges and they can be constructed out of pre-cast concrete sections. They are also faster to build than suspension bridges (PBS).

A new analysis of implementing alternatives for connecting Hatteras island need to be done. A ferry system in the outer banks has become a possibility as larger, faster, and lower draft vessels come on the market. Expanding the current NCDOT Ferry Division that services the Outer Banks community is a viable alternative to a bridge replacement if the pros and cons are properly examined. Because of the instability of a ferry system during evacuation, and their reduced passenger volume, a realistic ferry system has not been thoroughly explored. Expanding the ferry division would be initially expensive, but could prove cheaper in the long run then constructing and maintaining a bridge. Environmentally, ferries would require their routes to be dredged yet would allow Pea Island Wildlife Refuge to remain largely undisturbed depending on terminal placement. The reduced number of vehicles would be environmentally beneficial to the island. A ferry system would change the sociological composition of Hatteras Island. The large volume of tourists that the bridge accommodates would not be possible with any of proposed ferry systems. In order for a cable-stayed bridge to become a viable option, research would have to be conducted. If the islands were found to be able to support a cable-stayed bridge, this may
be the perfect alternative to the current options when it comes to the environmental and economic concerns surrounding the current options. With proper evaluation, either an expanded ferry system or cable-stayed bridge could prove to be an alternative to the proposed Bonner Bridge replacements.

**Conclusions (Class)**

Based on our findings of facts from the information presented above, our class has formulated the following conclusions:

- The Outer Banks is a valuable NC destination, economic engine, environmental landmark and rich with history.
- Bonner Bridge is not going to last so alternatives need to be considered. Due to the instability of the current bridge, all considerations must be evaluated and acted upon quickly.
- The projected life of the Outer Banks in this region is between 120-170 years (2008). At some unknown time prior, residents will not be able to continue living on the island.
- There are three viable alternatives for the replacement for the Bonner Bridge, two of which require the construction of a new bridge.
- Extensive studies have been done for the options of both bridges.
- Little recent and thorough research has been conducted on the alternative of a ferry system as a replacement option.
- All three options affect the environment, tourism and residential industries.
- Only two options -- the long bridge, and a ferry, address the chronic and expensive Highway 12 problem in the current bridge/road configuration.
- All three options have various numbers associated with implementation, so firm construction and maintenance cost estimates must be developed in order to fully decide which option is best.
- Based on the current budget that the NCDOT has for maintaining and construction of bridges, neither the long nor the short bridge options are financially viable.

**Recommendations (Class)**

Based on the available data and studies that have been complete to date, we recommend that:

- More thorough research should be conducted on ferry routes and ferry options as a third viable alternative.
- Only the options that directly address the disposition of NC Hwy 12 on Pea Island National Wildlife Refuge between the existing Bridge and Rodanthe should be considered.
References


