The Disasters and Politics of the Wheeling Bridge

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1.011

Executive Summary

The Wheeling Bridge was constructed in Wheeling, WV in 1849. The bridge connected the gap over the Ohio River between West Virginia and Ohio. It also connected the eastern and western sections of the national road. The bridge was designed by Charles Ellet and was the longest suspension bridge at the time of construction. Originally the cost of the bridge was estimated to be $120,000 but actually cost about $250,000.[1] The construction was funded by sale of stock and loans by the Wheeling Bridge Company.

After construction was complete the Bridge Company entered a costly legal battle with Pittsburgh, PA. Pittsburgh is located approximately 50 miles upstream from Wheeling. Pittsburgh claimed that the Wheeling Bridge obstructed steamboat traffic along the Ohio River thereby affecting the Pittsburgh economy. The legal battle went all the way to the U.S. Supreme Court. In May 1852 the Court decided that the bridge did indeed obstruct steamboat traffic and ordered that the bridge either be rebuilt higher or be torn down altogether. The residents of Wheeling, backed by the legislatures of Virginia and Indiana, decide to go to Congress in order to ask for the bridge to be declared part of a military and postal road. Three months after the court ruling, Congress decides to side with Wheeling and declare the bridge part of a postal and military road. The legal battle subsides until May 1854 when a strong gust of wind destroys the bridge.

After the bridge was destroyed, Pittsburgh seized the opportunity to continue the legal battle and returns to the Supreme Court to ask for an injunction preventing the reconstruction of the bridge. Ultimately the Court decided in favor of Wheeling since they claim that Congress has the right to declare postal and military roads.

The bridge was sold to the city of Wheeling in 1927 for $2.15 million dollars and is currently the oldest U.S. suspension bridge still in operation.[1]

History and Issues

*(see Appendix 1 for pictures and maps)

Since the early 1800's the Wheeling and Belmont Bridge Company considered constructing a bridge across the Ohio River in order to connect West Virginia to Ohio. The Federal Government approved the construction of the National Road in 1806. However, it did not reach Wheeling until 1818.[1] The National Road started in Baltimore and continued westwards through Ohio. At that time the Ohio River was one of the busiest rivers in the world. It offered a water route between Pittsburgh, Cincinnati and continued southward towards the developing areas of the United States. Wheeling was located at a critical location at the intersection of the National Road and the Ohio River.

In order to take advantage of Wheeling's location, the Bridge Company first decided to implement a ferry service across the Ohio River. This ferry was used to improve trade and mail service with the western sections of the United States and ran until the completion of the Wheeling Bridge.

At Wheeling the Ohio River creates a back channel behind Wheeling Island. The first bridge to be constructed in Wheeling was across this back channel. The Zane Brothers completed the bridge in 1836 at a cost of approximately $65,000 and a construction time of four years.[1] Although this was a major achievement for Wheeling, it did not yet provide a span across the main section of the Ohio River. Furthermore, the long construction time and cost overruns left the Zane Brothers greatly in debt. During the same year the back channel bridge was completed, the planning for construction of the Wheeling Bridge began.

In 1836 a civil engineer named Charles Ellet proposed a bridge across the Ohio River to the Bridge Company. Charles Ellet was born on January 1, 1810 in Penn's Manor, Pennsylvania and became a very influential bridge and railroad engineer. He worked on suspension bridges across the Shuylkill River in Pennsylvania and Niagara River. Additionally he "became chief engineer of the Central Railroad of Virginia and in 1853 built a railroad over the Blue Ridge at Rock Fish Gap, which was probably the most remarkable line then in existence."[1]

In 1836 when Ellet proposed the Ohio River crossing, the Bridge Company does not make any conclusive decisions. In 1841 Ellet presents another proposal to build a bridge for $120,000. At this point John Roebling, another famous bridge builder, decides to offer a similar proposal for $130,000.[1] Once again the Bridge Company does not make any conclusive decisions due to lack of funding. Although residents of Wheeling had asked the Federal Government to pay for the construction of the bridge, the government did not think this project was critical. The opportunity to build a bridge gathers strength when the state of Virginia allows the construction of a suspension bridge across the Ohio River instead of a pier bridge, which would greatly obstruct steamboat traffic. The state of Virginia also recognizes the Bridge Company and allows it to sell stock in March 1847.[1] Two months later the Bridge Company decides to finally begin the planning of the bridge.

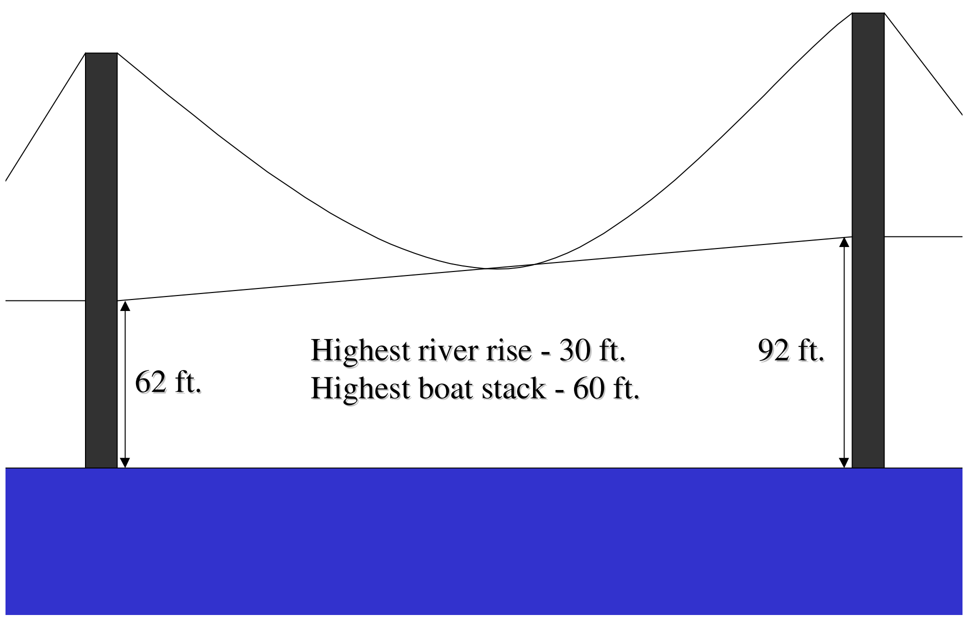
With funding from stock and loans and approval from the state, the Wheeling Bridge Company asks Ellet and Roebling to create a detailed presentation of their proposed bridges. Ellet proposes a 1010 ft. single span suspension bridge. Roebling proposes a double span suspension bridge with span length of less than 600 ft. Roebling's design is much safer and easier to build since the span is shorter. Ellet design is much more innovative and risky. A span of 1010 ft. had never been built before anywhere in the world. However, the Bridge Company decides to go with Ellet's plan since it will provide a much greater horizontal clearance for boats along the Ohio River.

In 1847, eleven years after Ellet first proposed the bridge, construction began on the Wheeling Bridge. Construction lasted for about two years and was affected by a number of factors. Heavy rainstorms and floods delayed much of the initial work and delivery of supplies. Furthermore, Ellet complained of the poor quality of workforce that he had been provided with. Ellet described the workers as "rowdies" and "rascals" and claimed that "it [the bridge] would not be done in 2,000 years with such people."[2] Eventually Ellet found a workforce to his liking and construction continued as planned. Problems with the availability of material caused more problems during the construction of the bridge. During the early stages of the project "one of the stone contractors defaulted, three months later a stone supplier also defaulted, and within a month a large delivery of iron of inferior quality had to be returned to the manufacturer."[2] Even with all these problems the construction of the bridge was not severely delayed.

In November 1849 the bridge opened with great fanfare and anticipation. However, this celebration was soon overshadowed by the legal battle with Pittsburgh. Pittsburgh is 50 miles away from Wheeling and lies upstream along the Ohio River. Pittsburgh's economy greatly depended on the traffic which flowed through the Ohio River. Upon the construction of the bridge Pittsburgh feared that "a bridge at Wheeling offered an opportunity for eastern and western railroads to unite south of their own city thereby diverting much of the trade of the Ohio valley."[2] But more importantly they claimed that the bridge interfered with navigation along the Ohio River.

The Wheeling Bridge was constructed so that at an average water level the maximum clearance was 92 ft. at the east end and 62 ft. at the west end. The highest boat stack at the time the bridge was designed was 60 ft. The highest river rise recorded was 30 ft., which happened approximately every two years.[1] Therefore the bridge was designed so that even at the highest river rise navigation through the Ohio River would still be possible.

Wheeling Bridge Diagram



In order to gain evidence against the bridge, Pittsburgh built steamboats with 80 ft. stacks and sent them down the Ohio River.[1] As they approached the bridge they did not stop but instead purposely crashed into the bridge. This caused major damage on the stacks of the steamboats. This evidence was used to prove that the bridge obstructed navigation along the Ohio River.

The Wheeling Bridge Company offered a solution to Pittsburgh's accusations. They suggested that all steamboats be equipped with retractable stacks so that as the steamboats passed under the bridge the stacks could be lowered. Pittsburgh objected claiming that lowering stacks greatly slowed down the speed of the steamboat and was inconvenient to have to lower the stacks every time a steamboat passed through Wheeling. This relatively cheap technology had already been implemented in many but no all steamboats. In fact, steamboats passing through the Allegheny and Monongahela Rivers near Pittsburgh had to lower their chimneys to pass through canals. Pittsburgh did not complain about this situation.

Although Pittsburgh claimed that their primary concern was the impediment of navigation along the Ohio River, their true concern was the diversion of trade through Wheeling. Their fears were realized when the B&O railroad decided to create its terminus at Wheeling instead of Pittsburgh because of the construction of the bridge.[2] This decision greatly boosted the Wheeling economy and further aggravated the rivalry between the two cities.

After the completion of the bridge Pittsburgh decides to go to the Supreme Court and claims that the Wheeling Bridge obstructs navigation through the Ohio River. The legal battle lasts for about two years. In May 1852 the Supreme Court rules in favor of Pittsburgh and demands that the bridge be reconstructed to meet adequate specifications or be removed altogether.[2] This decision was a huge blow for the Wheeling Bridge Company. Instead of accepting the decision the Bridge Company decides to dispute the decision in Congress. The Bridge Company is supported by the legislatures of Virginia and Indiana. They ask Congress to declare the bridge part of a postal and military road. Two months after the court decision, in August 1854 Congress grants a major victory for the Bridge Company and decides to declare the bridge an official postal and military road.[2] This in effect ends the initial legal battle between the two cities.

For about two years the Wheeling Bridge enjoys a period of normality and is experiencing great amounts of pedestrian and cart traffic. On May 16, 1854 the troubles for the Wheeling Bridge return. A powerful windstorm destroys the Wheeling Bridge and sends the road and cables crashing into the Ohio River. The local newspaper, The Wheeling *Intelligencer*, recounts how the bridge collapsed:

> For a few moments we watched it with breathless anxiety, lunging like a ship in the storm; at one time it rose to nearly the height of the towers then fell, and twisted and writhed, and was dashed almost bottom upward. At last there seemed to be a determined twist along the entire span, about one half of the flooring being nearly reversed, and down went the immense structure from its dizzy height to the stream below, with an appalling crash and roar.[2]

Pittsburgh is elated by the news and sends a steamboat named Pennsylvania down the Ohio River. As the steamboat passes through the area where the bridge once stood, it lowers its stacks to mock the people of Wheeling.[1] This story proves the deep rivalry that characterized the relationship between these two cities.

After the collapse of the bridge Pittsburgh decides to continue the legal battle. The city goes once again to the Supreme Court to ask for an injunction preventing the reconstruction of the bridge. Since the Supreme Court is not in session at the time, the

Chief Justice Robert Grier grants the injunction. Many Wheeling citizens accused Grier of corruption since he was from Pennsylvania and automatically favored Pittsburgh. The Bridge Company does not obey the injunction and continues the reconstruction of the bridge.

When the Supreme Court is back in session in December 1854 the majority sides with Wheeling. Their main reason is that Congress has the right to declare postal and military roads. Since Congress favored the reconstruction of the bridge, the Supreme Court found it unjustifiable to intervene. This decision finally ends the long and costly legal battle between the two rival cities.

Ellet was greatly grieved by the collapse of the bridge and returns to Wheeling to construct a temporary bridge at a cost of $17,000.[1] This one way temporary bridge took three months to build and would serve as a connection while they redesigned a more stable permanent bridge. William McComas was hired as the head engineer during the reconstruction of the second bridge. The reconstruction took approximately a year at a cost of about $40,000.[1] McComas studied Roebling's bridge designs and incorporated extra cables into the new design to strengthen the bridge. The bridge was reconstructed with much of the original material that was salvaged from the river.

Benefits

The construction of the bridge greatly boosted the Wheeling economy by increasing trade through the city. The decision by the Baltimore & Ohio Railroad to create a terminus at Wheeling further improved the economic success of the city. Not only did the city itself experience an economic boost but also the cities around the

National Road. By connecting the eastern and western sections of the National Road inter-state trade increased. Also, bridge technology greatly benefited by the construction of the Wheeling Bridge since it was an innovative design that had never been tested before. Although the bridge ultimately collapsed, it currently provides civil engineers with a case study for bridge failure.

The Wheeling Bridge proved to be an important postal and military road. Before the completion of the bridge, mail delivery in the region was unreliable and slow. Delivery of mail was greatly expedited due to the connection of the National Road. Also in the 1860's the bridge proved to be an extremely important military road during the Civil War. The northern states greatly benefited from this bridge since it allowed troops and armor to be easily moved from one part of the country to another.

Costs

Total construction costs for the bridge including the reconstruction were approximately $400,000.[1] In addition to the construction costs, the Bridge Company had to pay for the costly legal battle against Pittsburgh. This cost was in the tens of thousands of dollars.

From Pittsburgh's point of view, the bridge cost them trade and the terminus of the B&O railroad. Although the bridge may have taken some trade away from Pittsburgh, it did not have a major impact on the economy of Pittsburgh since they were still able to become a much more prosperous city than Wheeling. Pittsburgh also incurred great costs from the legal battle that it ultimately lost.

Risks & Uncertainties

During any major construction project many risks and uncertainties must be taken into consideration. Four main risks characterized this project: risk of under-designing the bridge, risk of building the longest suspension bridge in the world, risk of underestimating riders to pay tolls and justify the project, and risk of underestimating cost and length of construction. Some uncertainties in the project include: uncertainty in the state of the future Wheeling economy, uncertainty in weather patterns that could destroy the bridge, and uncertainty in floods that would cause the bridge to obstruct navigation.

The risk of under-designing the bridge was especially important in this project since it was a technologically elaborate design. Bridge building was a relatively new field at the time so the risks of an engineering disaster were definitely relevant. At the time it was constructed the Wheeling Bridge was the longest single span suspension bridge. Charles Ellet and John Roebling were both asked to bid for the construction of the bridge. Ellet was not as educated as Roebling, however his unique single span bridge design was more impressive than the traditional bridge with river piers that Roebling proposed. Given that a bridge this long had never been constructed the risks of failure were markedly greater. Although the bridge was designed to carry much greater vertical loads than it would ever encounter, the horizontal load that it experienced in 1854 due to a storm led to its demise. Ellet's inexperience and bold design caused the collapse of the bridge. This risk could have been addressed with insurance. However, the Bridge Company did not have insurance for the bridge and was forced to reconstruct it with new loans. Also Ellet could have mitigated this risk of under-design by consulting with other civil engineers and ensuring the bridge could withstand both vertical and horizontal forces. The risk of engineering failure is a factor that should play a big role in the planning stages especially with innovative projects such as the Wheeling Bridge.

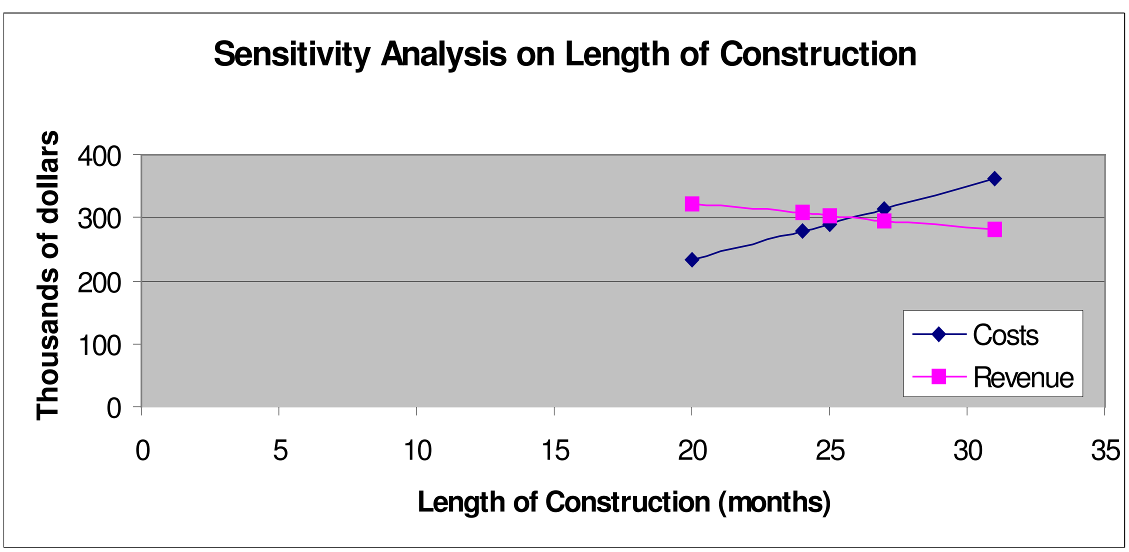
Another major risk is underestimating the amount of riders that will be using the bridge. This estimate is important since it is necessary to know if there is a great enough demand to justify the construction of the project. If tolls will not cover the costs of the project then the project should be reconsidered. Since ferries were being used before the bridge was constructed, the project managers were able to mitigate this risk by providing a good estimate on how many people would be using the bridge. Sensitivity analysis will be helpful in determining whether or not the project will be profitable considering the risk of underestimating tolls.

The risk of underestimating cost and length of construction is probably the greatest amongst these four risks. The cost of the project could vary greatly based on many factors. The price of materials could be greater than anticipated. Also the length of construction could dramatically increase the total cost of the bridge. Hiring reliable and responsible employees can mitigate this risk. It can also be resolved by forcing the construction company to assure the owner that the project will be completed at a certain date. If it is not completed the company will incur all further costs. This form of insurance can greatly decrease the risk of underestimating the length of construction.

Changes in the state of the economy pose a great uncertainty. If the country enters a depression, commercial traffic over the bridge could drastically decrease. This decrease in tolls could lead the Bridge Company to declare bankruptcy when it is no longer able to operate the bridge and pay its loans. However, the interest rates on the loan could decrease if the government attempts to boost the economy. This could relieve some of the stress on the financial situation of the bridge. These uncertainties must be taken into consideration during the planning of the bridge. The best way to face these uncertainties is to do sensitivity analysis on the project. By doing sensitivity analysis the project manager will be able to better understand the economic limitations of the project.

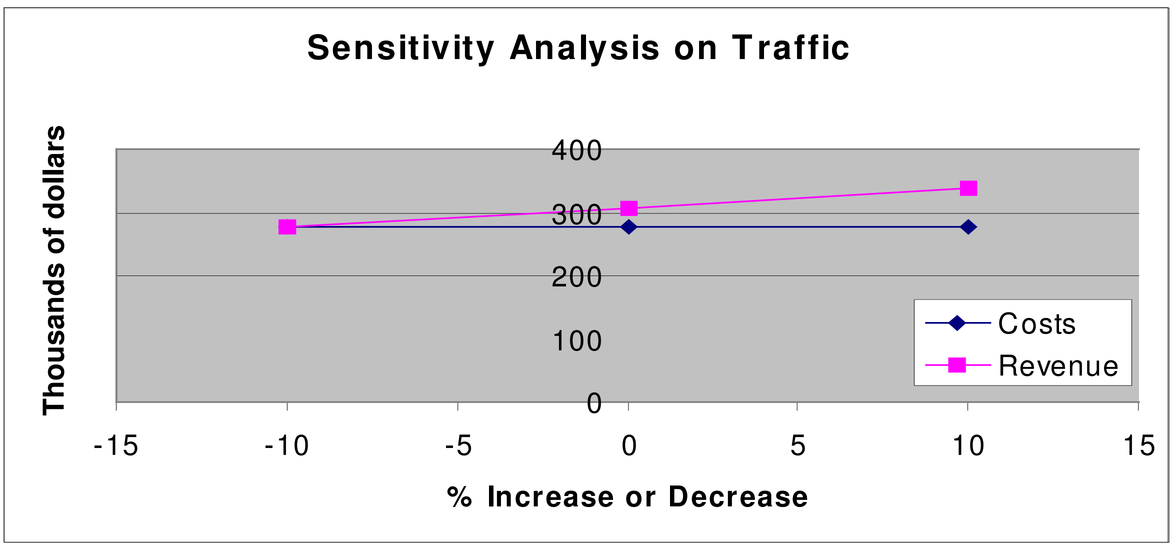
Another great uncertainty particularly with bridges is weather patterns. There is great uncertainty as to when there will be a flood or major windstorm. If a windstorm occurs it has the potential of destroying the bridge as was the case with the Wheeling Bridge. Over-engineering the bridge, thereby making the bridge less likely to collapse during a windstorm, can reduce this uncertainty. Furthermore, if a flood occurs steamboat traffic will be greatly impeded. This uncertainty can be addressed by allowing enough vertical clearance for steamboats to pass even during the worst recorded floods in history. Ellet actually designed the bridge precisely so that steamboat traffic would not be impeded even during occasional floods as discussed earlier.

The table and graphs on Appendix 3 show sensitivity analysis for the Wheeling Bridge project. I have taken the base case to be the following: interest rate 10%, discount rate 12%, and length of construction 24 months. As shown in the graphs the most sensitive variable is length of construction. Therefore minimizing the length of



construction should be given great priority in order to make this a successful project. A few months can make the difference between a profitable and a non-profitable project. Anything above 26 months makes the project unprofitable.

Another variable that greatly affects the profitability of the project is traffic and tolls. If traffic decreases by 10% from the expected, the project is no longer profitable. A 10% increase in tolls or traffic will double the profitability of the project. An increase in tolls should be considered if studies show that it will not greatly decrease the traffic on the bridge.



As shown by the table in Appendix 3 there are many variations that will make this project profitable. Of the 18 variations only 5 are unprofitable.

Scenarios

The following table shows a list of three scenarios: terrible weather during construction, economic depression, and a terrorist attack or other calamity halfway through construction of the bridge. All costs are in thousands of dollars.

Scenarios	Interest (%)	Discount Rate (%)	Length of Construction (months)	Present Worth of Costs in 1849	Present Worth of Revenue	Cost/Resident	Profit
Base Case	10	12	24	283.191	384.131	0.071	100.94
Destructive Weather	12	12	27	326.502	374.235	0.082	57.63
Depression	5	12	25	279.739	325.649	0.07	45.91
Terrorist Attack	12	12	31	378.146	382.736	0.095	4.59

Destructive weather during construction could delay the time for completion and could cause the bank to become skeptical about the profitability of the project. This scenario would lead to a decrease in profit of about $43,000. An economic depression during the construction could lead to a decrease in interest rates as the government attempts to boost the economy. It could also increase the length of time because of delays due to material delivery and worker efficiency. This scenario would cause a decrease in profit of approximately $55,000. As shown in the table, the scenario that would cause the greatest damage is a terrorist attack. This scenario would greatly increase the length of construction and would cause the bank to be more hesitant about giving loans. Also the costs of construction would greatly increase causing a decrease in profit of about $96,000.

Cost & Revenue Analysis

*(refer to Appendix 2 for detailed Cost and Revenue spreadsheets)

In order to analyze the construction costs of the Wheeling Bridge I have broken the project down to three phases: initial construction, temporary reconstruction, and permanent reconstruction. I have identified five major costs: engineering fees, project management costs, preparation costs, construction, and interest. I assumed that interest costs were incurred based on the monthly expenses. The net present value of all costs has been calculated to the year 1849 when the first bridge was completed.

The first bridge was constructed in 24 months at a cost of approximately $259,000. After the bridge collapsed in 1854 a temporary bridge was constructed in 3 months at a net present cost of $10,152. Construction costs were significantly lower than the first since the bridge was not as wide and complex. In 1860 a permanent replacement is constructed at a net present cost of $13,070. The construction costs for this bridge were also cheaper than the original since much of the material from the original bridge was reused. The total net present worth in 1849 of construction costs is $283,191.

The yearly revenue and costs spreadsheet shows cash flows beginning after the first completion of the bridge in 1849 until it was sold to the city in 1927. This spreadsheet does not include construction costs but instead shows the costs of operation and renovation and the revenues from tolls. Also, tolls are shown for various types of users. Using these numbers, the yearly revenue from tolls is approximately $47,550. Yearly operational costs increase gradually from about $1,000 to about $5,000. Major renovations are completed in years 11 and 23.[1] These renovations included strengthening the cables and reconstructing the sidewalk across the bridge.

The spreadsheet shows that the cumulative present worth of revenues will exceed the present worth of construction costs at approximately year 12. At this point the Bridge Company has earned a cumulative revenue of $285,760 which surpasses the construction costs of $283,191. The return on investment using the net present worth values is approximately 16%. Although this is high, the Bridge Company is greatly indebted by the legal costs. If this bridge had not provided such a high return on investment the legal battle might have bankrupted the company. However, since this bridge proved to be extremely profitable, the Bridge Company was not only able to survive a costly legal battle but also a natural disaster.

The invention of the mass production of cars in the 1920's greatly increases the revenue of the bridge. In 1927 the city of Wheeling becomes interested in purchasing the profitable bridge. The Bridge Company agrees to sell it to the city for $2.15 million. The total profit of the project was approximately $100,940 using net present worth values for cost and revenue in 1849.

Comparison with Tacoma Narrows, Humber, and Carquinez Strait Bridges

The story of the Tacoma Narrows Bridge, built almost a century later, is incredibly similar to that of the Wheeling Bridge. Both bridges were very elegant and innovative in design and took two years to complete. Unfortunately the designers of both bridges compromised safety for aesthetics. The Tacoma Narrows Bridge collapsed four months after it was built while the Wheeling Bridge lasted about five years. Both bridges collapsed after reaching resonance frequency due to a windstorm. Some may wonder why the designers of the Tacoma Narrows Bridge did not correct the mistakes that were made with the Wheeling Bridge. The main reason is because engineers did not realize what had gone wrong with the Wheeling Bridge. They knew it was caused by structural failure but did not understand the physics behind the collapse. They rebuilt the Wheeling Bridge by adding more cables but they did not understand what specifically needed to be changed. While the Wheeling Bridge was rebuilt three months after the collapse, the Tacoma Narrows was rebuilt ten years after it collapsed. The collapse of these two bridges is surprisingly similar. Unfortunately the collapse of the Tacoma Narrows Bridge was not avoided even after such a similar collapse a century before.

Similar to the Wheeling Bridge, the Humber Bridge in England was the longest suspension bridge when it was completed in 1981. Unlike the Wheeling Bridge, the Humber Bridge did not collapse and continues to be a structurally successful bridge. However, the Humber Bridge suffered economic problems. Although the bridge was intended to boost the local economy and increase traffic around the area, it was a failure. The predicted economic boost and ridership was erroneous since commercial traffic makes up no more than 6% (according to Alia Barton's presentation). On the other hand, the Wheeling Bridge was an economic success that boosted the local economy and increased inter-state trade. The Wheeling Bridge made profit after about fifteen to twenty years even with the costs of the legal battle. However, the Humber Bridge is far from paying for itself. These two bridges both suffered failures, one economic and the other structural. In the case of these two bridges, economic failure proved to be much worse than structural failure since economic failure cannot be easily fixed.

Unlike the three previous bridges, the Carquinez Strait Bridges in San Francisco were both structurally and economically successful. Although the first and second bridges, built in 1927 and 1958 respectively, were found to be structurally unstable, the problem was corrected before a collapse could occur. Unlike the Wheeling Bridge, the Carquinez Bridge was constructed using state money. The Wheeling and Belmont Bridge Company privately constructed the Wheeling Bridge. Private construction of the bridge leads to many additional risks such as stock sale and loans. If the government provides funding for the bridge then the risk of failure decreases since the government has a greater income base than a private company.

Project Evaluation Critique and Conclusions

The Wheeling Bridge Company was able to successfully capitalize on the great demand to link the eastern and western United States. The fact that the idea of bridging the Ohio River developed over 30 years shows the careful and methodical process that took place. The Bridge Company was in no hurry of quickly and recklessly developing the project. Instead they carefully let the idea develop in order to assure the success of the bridge. The progressive steps they took towards the development of a bridge reduced the risks of failure. First they started by providing a ferry service. This service allowed them to gauge the demand for a link between West Virginia and Ohio. Seeing the demand was great, they proceeded by asking the state government to allow the construction of a suspension bridge. Once the state approved the construction, the Bridge Company asked for designs by Ellet and Roebling and chose the design they thought would least obstruct navigation. By choosing Ellet's design they were able to provide a clear span under the bridge allowing maximum navigability. Although the construction did suffer some delays, overall it proceeded as scheduled. It did however run over budget by about $120,000.[1] However, the demand was so great that the bridge was still profitable.

The only criticism that one may have of the project evaluation process is the Bridge Company's failure to foresee the legal battle with Pittsburgh. However, this criticism is not altogether valid since Pittsburgh did not object to the bridge at all until construction was complete. Furthermore, the Bridge Company considered navigability through the Ohio River as a top priority during the design phase of the bridge. Overall the project evaluation process taken by the Bridge Company was extremely successful since they carefully achieved progressive steps towards the completion of the bridge. The Bridge Company assessed the success of the bridge at each step of the development and did not rush through the process thereby assuring the success and profitability of the project. Although the project suffered many setbacks, such as the legal battles and natural disaster, it eventually became very profitable and was a major factor in the development of the Wheeling economy.

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Costs

Key Variables		
Interest Rate on loan	10	%
Nominal Rate	9.57	%
Length of Construction	24	months
Owner's Discount Rate	12	%

Summary	
Present Worth of Costs in 1849	283.191
Present Worth of Revenue	384.131
Residents in Wheeling in 1849	4000
Cost of Bridge/Resident	0.071
Profit	100.940

***all numbers in thousands of dollars**
***discount all numbers to the end of construction in 1849**

Wheeling Bridge: 1847-1849

Month	Engineering Fees	Project Management	Prep. Of Case	Construction Costs	Interest Costs	Total Monthly Cost	Cummulative Costs	Cumm. Costs After Interest	PW of Mthly Costs
1	0.167	0.050	2		0.000	2.217	2.217	2.217	2.195
2	0.167	0.050			0.019	0.217	2.434	2.453	0.234
3	0.167	0.050			0.022	0.217	2.670	2.693	0.237
4	0.167	0.050			0.024	0.217	2.910	2.934	0.239
5	0.167	0.050			0.026	0.217	3.151	3.177	0.241
6	0.167	0.050			0.028	0.217	3.394	3.422	0.243
7	0.167	0.050		9.375	0.108	9.592	13.014	13.123	9.604
8	0.167	0.050		9.375	0.189	9.592	22.715	22.904	9.684
9	0.167	0.050		9.375	0.271	9.592	32.496	32.767	9.765
10	0.167	0.050		9.375	0.353	9.592	42.359	42.712	9.847
11	0.167	0.050		9.375	0.436	9.592	52.304	52.740	9.929
12	0.167	0.050		9.375	0.519	9.592	62.332	62.851	10.011
13	0.167	0.050		9.375	0.604	9.592	72.443	73.047	10.095
14	0.167	0.050		9.375	0.689	9.592	82.639	83.328	10.179
15	0.167	0.050		9.375	0.774	9.592	92.920	93.694	10.264
16	0.167	0.050		9.375	0.861	9.592	103.286	104.147	10.349
17	0.167	0.050		9.375	0.948	9.592	113.739	114.687	10.435
18	0.167	0.050		9.375	1.036	9.592	124.279	125.314	10.522
19	0.167	0.050		9.375	1.124	9.592	134.906	136.030	10.610
20	0.167	0.050		9.375	1.214	9.592	145.622	146.836	10.699
21	0.167	0.050		9.375	1.304	9.592	156.428	157.731	10.788
22	0.167	0.050		9.375	1.394	9.592	167.323	168.718	10.878
23	0.167	0.050		9.375	1.486	9.592	178.310	179.796	10.968
24	0.167	0.050		9.375	1.578	9.592	189.388	190.966	11.060
25	0.167	0.050		9.375	1.671	9.592	200.558	202.229	11.152
26	0.167	0.050		9.375	1.765	9.592	211.821	213.586	11.245
27	0.167	0.050		9.375	1.860	9.592	223.178	225.038	11.338
28	0.167	0.050		9.375	1.955	9.592	234.630	236.586	11.433
29	0.167	0.050		9.375	2.051	9.592	246.178	248.229	11.528
30	0.167	0.050		9.375	2.149	9.592	257.821	259.970	11.624
							Present Worth in 1849	**259.970**	

After Wheeling Bridge is destroyed a temporary bridge is built: May 1854 - August 1854

Month	Engineering Fees	Project Management	Prep. Of Case	Construction Costs	Interest Costs	Total Monthly Cost	Cumm. Costs	Cumm. Costs After Interest	PW of Mthly Costs
1	0.167	0.050	0	5.666	0.000	5.883	5.883	5.883	5.825
2	0.167	0.050		5.666	0.094	5.883	11.766	11.860	5.918
3	0.167	0.050		5.666	0.148	5.883	17.743	17.891	5.971

							Present Worth 1849	**10.152**	

Permanent Bridge is built: 1859-1860

Month	Engineering Fees	Project Management	Prep. Of Case	Construction Costs	Interest Costs	Total Monthly Cost	Cumm. Costs	Cumm. Costs After Interest	PW of Mthly Costs
1	0.208	0.050	1		0.000	1.258	1.258	1.258	1.246
2	0.208	0.050			0.012	0.258	1.516	1.528	0.267
3	0.208	0.050			0.015	0.258	1.786	1.801	0.270
4	0.208	0.050			0.017	0.258	2.059	2.076	0.272
5	0.208	0.050			0.019	0.258	2.334	2.354	0.275
6	0.208	0.050		3.125	0.048	3.383	5.737	5.784	3.397
7	0.208	0.050		3.125	0.076	3.383	9.167	9.244	3.425
8	0.208	0.050		3.125	0.105	3.383	12.627	12.732	3.454
9	0.208	0.050		3.125	0.134	3.383	16.115	16.249	3.482
10	0.208	0.050		3.125	0.164	3.383	19.632	19.796	3.511
11	0.208	0.050		3.125	0.193	3.383	23.179	23.372	3.541
12	0.208	0.050		3.125	0.223	3.383	26.755	26.978	3.570
13	0.208	0.050		3.125	0.253	3.383	30.361	30.614	3.600
14	0.208	0.050		3.125	0.283	3.383	33.997	34.280	3.630
15	0.208	0.050		3.125	0.314	3.383	37.663	37.977	3.660
16	0.208	0.050		3.125	0.345	3.383	41.360	41.705	3.691
17	0.208	0.050		3.125	0.376	3.383	45.088	45.464	3.722
							Present Worth 1849	**13.070**	

Abraham Reyes
1.011
4/25/2003

Yearly Revenues and Costs

Key Variables		
Interest Rate on loan	10	%
Nominal Rate	9.57	%
Length of Construction	24	months
Owner's Discount Rate	12	%

Summary	
Approximate Annual Revenue	47550
# Years Collecting Tolls	77
Bridge Sold in Year:	78
Present Worth in 1849	384131.11
Return on investment (%)	16.79

***all numbers in dollars**

Year	Type of Cost	Operational Cost	Type of Revenue	Yearly Revenue	PW of Revenue
1	Toll Keepers	-1000	Tolls	47550	41562.50
2	Toll Keepers	-1000	Tolls	47550	78671.88
3	Toll Keepers	-1000	Tolls	47550	111805.25
4	Toll Keepers	-1000	Tolls	47550	141388.61
5	Toll Keepers	-1000	Tolls	47550	167802.33
6	Toll Keepers	-1000	Tolls	47550	191386.01
7	Toll Keepers	-1000	Tolls	47550	212442.87
8	Toll Keepers	-1000	Tolls	47550	231243.63
9	Toll Keepers	-1000	Tolls	47550	248030.03
10	Toll Keepers	-1000	Tolls	47550	263017.88
11	Renovation	-10000	Tolls	47550	273812.61
12	Toll Keepers	-1000	Tolls	47550	285760.84
13	Toll Keepers	-1000	Tolls	47550	296428.89
14	Toll Keepers	-1000	Tolls	47550	305953.95
15	Toll Keepers	-1000	Tolls	47550	314458.46
16	Toll Keepers	-1000	Tolls	47550	322051.77
17	Toll Keepers	-1000	Tolls	47550	328831.51
18	Toll Keepers	-1000	Tolls	47550	334884.86
19	Toll Keepers	-1000	Tolls	47550	340289.63
20	Toll Keepers	-2000	Tolls	47550	345011.65
21	Toll Keepers	-2000	Tolls	47550	349227.74
22	Toll Keepers	-2000	Tolls	47550	352992.11
23	Renovation	-6000	Tolls	47550	356058.00
24	Toll Keepers	-2000	Tolls	47550	359058.93
25	Toll Keepers	-2000	Tolls	47550	361738.33
26	Toll Keepers	-2000	Tolls	47550	364130.65
27	Toll Keepers	-2000	Tolls	47550	366266.65
28	Toll Keepers	-2000	Tolls	47550	368173.80
29	Toll Keepers	-2000	Tolls	47550	369876.61
30	Toll Keepers	-2000	Tolls	47550	371396.97
31	Toll Keepers	-2000	Tolls	47550	372754.44
32	Toll Keepers	-2000	Tolls	47550	373966.46
33	Toll Keepers	-2000	Tolls	47550	375048.63
34	Toll Keepers	-2000	Tolls	47550	376014.85
35	Toll Keepers	-2000	Tolls	47550	376877.54
36	Toll Keepers	-2000	Tolls	47550	377647.81
37	Toll Keepers	-2000	Tolls	47550	378335.54
38	Toll Keepers	-2000	Tolls	47550	378949.59
39	Toll Keepers	-2000	Tolls	47550	379497.85
40	Toll Keepers	-2000	Tolls	47550	379987.37
41	Toll Keepers	-4000	Tolls	47550	380405.25
42	Toll Keepers	-4000	Tolls	47550	380778.35
43	Toll Keepers	-4000	Tolls	47550	381111.48
44	Toll Keepers	-4000	Tolls	47550	381408.92
45	Toll Keepers	-4000	Tolls	47550	381674.49
46	Toll Keepers	-4000	Tolls	47550	381911.60
47	Toll Keepers	-4000	Tolls	47550	382123.31
48	Toll Keepers	-4000	Tolls	47550	382312.34
49	Toll Keepers	-4000	Tolls	47550	382481.11
50	Toll Keepers	-4000	Tolls	47550	382631.80
51	Toll Keepers	-4000	Tolls	47550	382766.35
52	Toll Keepers	-4000	Tolls	47550	382886.48
53	Toll Keepers	-4000	Tolls	47550	382993.74
54	Toll Keepers	-4000	Tolls	47550	383089.50
55	Toll Keepers	-4000	Tolls	47550	383175.01
56	Toll Keepers	-4000	Tolls	47550	383251.35
57	Toll Keepers	-4000	Tolls	47550	383319.52
58	Toll Keepers	-4000	Tolls	47550	383380.38
59	Toll Keepers	-4000	Tolls	47550	383434.72
60	Toll Keepers	-5000	Tolls	47550	383482.13
61	Toll Keepers	-5000	Tolls	47550	383524.45
62	Toll Keepers	-5000	Tolls	47550	383562.24
63	Toll Keepers	-5000	Tolls	47550	383595.98
64	Toll Keepers	-5000	Tolls	47550	383626.11
65	Toll Keepers	-5000	Tolls	47550	383653.01
66	Toll Keepers	-5000	Tolls	47550	383677.02
67	Toll Keepers	-5000	Tolls	47550	383698.47
68	Toll Keepers	-5000	Tolls	47550	383717.61
69	Toll Keepers	-5000	Tolls	47550	383734.71
70	Toll Keepers	-5000	Tolls	47550	383749.97
71	Toll Keepers	-5000	Tolls	47550	383763.60
72	Toll Keepers	-5000	Tolls	47550	383775.77
73	Toll Keepers	-5000	Tolls	47550	383786.63
74	Toll Keepers	-5000	Tolls	47550	383796.33
75	Toll Keepers	-5000	Tolls	47550	383804.99
76	Toll Keepers	-5000	Tolls	47550	383812.72
77	Toll Keepers	-5000	Tolls	47550	383819.63
78			Sold	2150000	384131.11

Tolls

Types	Price (in dollars)	Amount per Year	Yearly Revenue
foot passengers	0.05	10000	500
man and horse	0.1	5000	500
1 horse wagon	0.2	5000	1000
2 horse wagon	0.25	5000	1250
3 horse wagon	0.25	4000	1000
4 horse wagon	0.4	3000	1200
5 horse wagon	0.6	2000	1200
6 horse wagon	0.75	1000	750
4 horse stagecoach	1.25/mth	60	75
western stages	2000/yr	20	40000
fine for horses exceeding walk	5	15	75
TOTAL			**47550**

*Assume tolls were collected starting in 1849 to the time the bridge was sold to the state in 1927

*All data was acquired from the following website:
http://wheeling.weirton.lib.wv.us/landmark/bridges/susp/bridgdex.htm

*Costs of bridge are surpassed in year 12

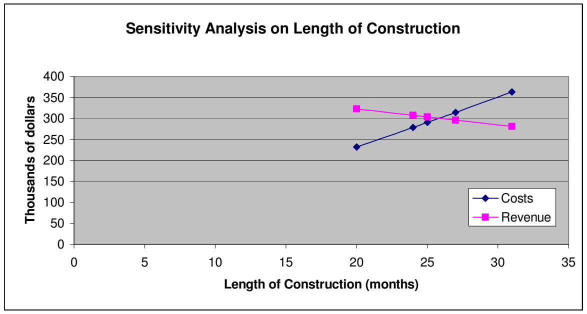
Sensitivity Analysis

*see graphs on following pages
*numbers in thousands of dollars

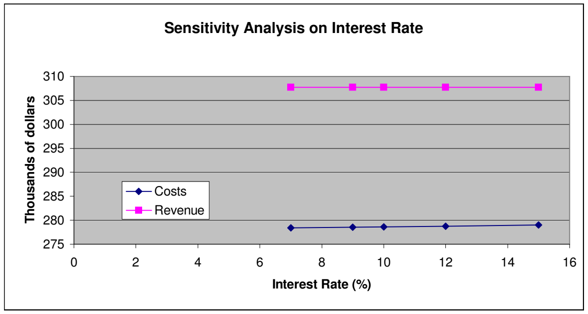
Interest (%)	Discount Rate (%)	Length of Construction (months)	Present Worth of Costs in 1849	Present Worth of Revenue	Cost/Resident	Profit
10	8	24	291.645	577.047	0.073	285.402
10	10	24	287.013	460.779	0.072	173.766
10	15	24	278.637	307.752	0.07	29.115
10	17	24	276.214	271.804	0.069	-4.41
10	20	24	273.279	231.316	0.068	-41.963
7	15	24	278.431	307.752	0.07	29.321
9	15	24	278.568	307.752	0.07	29.184
10	15	24	278.637	307.752	0.07	29.115
12	15	24	278.716	307.752	0.07	29.036
15	15	24	278.987	307.752	0.07	28.765
10	15	20	232.253	323.269	0.058	91.016
10	15	24	278.636	307.752	0.07	29.116
10	15	25	290.475	303.873	0.073	13.398
10	15	27	314.448	296.115	0.079	-18.333
10	15	31	363.606	280.598	0.091	-83.008
Traffic		% Increase or Decrease				
Decrease by 10%		-10	278.636	276.069	0.07	-2.567
Base		0	278.636	307.752	0.07	29.116
Increase by 10%		10	278.636	339.434	0.07	60.798
Tolls						
Base		0	278.636	307.752	0.07	29.116
Increase by 10%		10	278.636	339.451	0.07	60.815

Observations
The bridge is no longer profitable if:
-The length of construction surpasses 26 months at a discount rate of 15% and interest rate of 10%
-The discount rate surpasses approximately 16% at an interest rate of 10% and a length of construction of 24 months

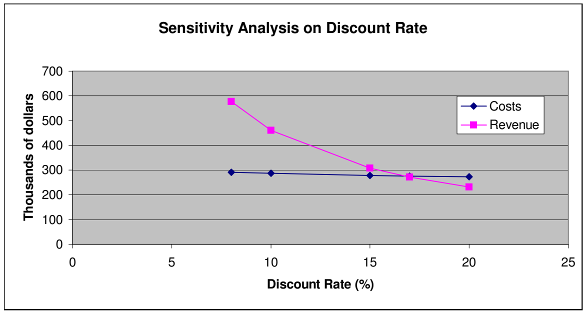
*As shown in the table above there are many variation in interest rate, discount rate, and length of construction that will justify the building of the bridge.



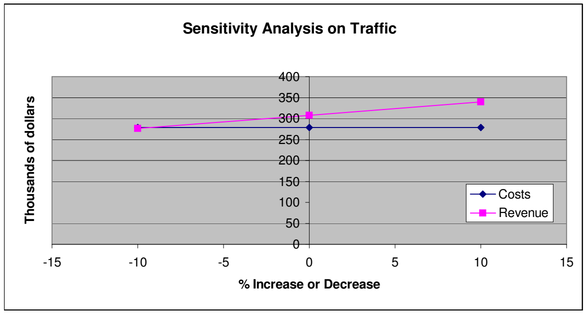
Sensitivity Analysis on Length of Construction



Sensitivity Analysis on Interest Rate



Sensitivity Analysis on Discount Rate



Sensitivity Analysis on Traffic