



Small Commercial Building Design in Canton, Maine

A Major Qualifying Project to be submitted to the faculty of
Worcester Polytechnic Institute in partial fulfillment of the
requirements for the Degree of Bachelor of Science

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Abstract

Our major qualifying project combined structural design with Building Information Modeling (BIM) technology. We applied our knowledge of wood structures to the revitalization of downtown Canton, Maine. The scope of our project entailed design and analysis of three buildings and a snowmobile bridge. Two of the buildings were new construction and one was an old firehouse requiring structural restoration. After evaluating the town's needs, we created three dimensional BIM models using Revit Architecture and Revit Structures. These models were then exported into Google Earth where they were placed on the actual terrain, enabling a more accurate vision of the downtown area.

Our final project provides structural analysis, cost estimates, and a visual representation of the entire redevelopment potential. We hope that these designs will be built in the future by the residents of Canton. Adding them to the area would greatly increase the tourism and provide more services for current residents. This project has the potential to become more than Google Earth images, and could eventually contribute to the restoration of Canton, Maine.

Literature Review

Project Overview

The purpose of this Major Qualifying Project is to investigate the revitalization of a portion of the town of Canton, ME and create feasible designs for the construction and renovations of three buildings and a bridge in the downtown area. There are two empty lots where small commercial buildings could be constructed; one could be used as an indoor flea market and farmers market, and the other could be used as an ice cream parlor and laundromat, with an apartment included on the second floor. An abandoned fire house in bad condition with a collapsing roof is going to be investigated to determine if it can be renovated, or if demolition and rebuilding is a better option. It could be used as a small commercial space on the first floor and an apartment on the second. A snowmobile trail runs through Canton, Maine, but there is currently no bridge across the river providing access to the downtown area. The final component of our project is to design a bridge that will provide this access and re-use the three abandoned concrete bridge piers and two abutments currently in the middle of the river.

Canton, ME

Current Conditions

The town of Canton is located in Oxford County, in western Maine. It has a population of approximately 1,100 (July 2008), and has not experienced much growth since 1870 when the population was 984 residents (Historical Sketch, 2009). Today the downtown area consists of a few shops, and only has one main intersection although 50 years ago the downtown area had many small shops and businesses. A lake used for recreation as

well as notable snowmobile trails draw in tourists and visitors throughout the year. In this rural community, the most common industries for residents to work in are construction and paper manufacturing for males, and healthcare and education for females (City-Data.com, 2008). Because of the remote location of the town, residents have to drive between 15 and 20 miles to reach many necessary services such as grocery stores, discount department stores, malls and restaurants. Many of the businesses in town, such as the convenience store, are designed to attract tourists and gain much of their profit from the snowmobiling population in the winter (2008 IQP).

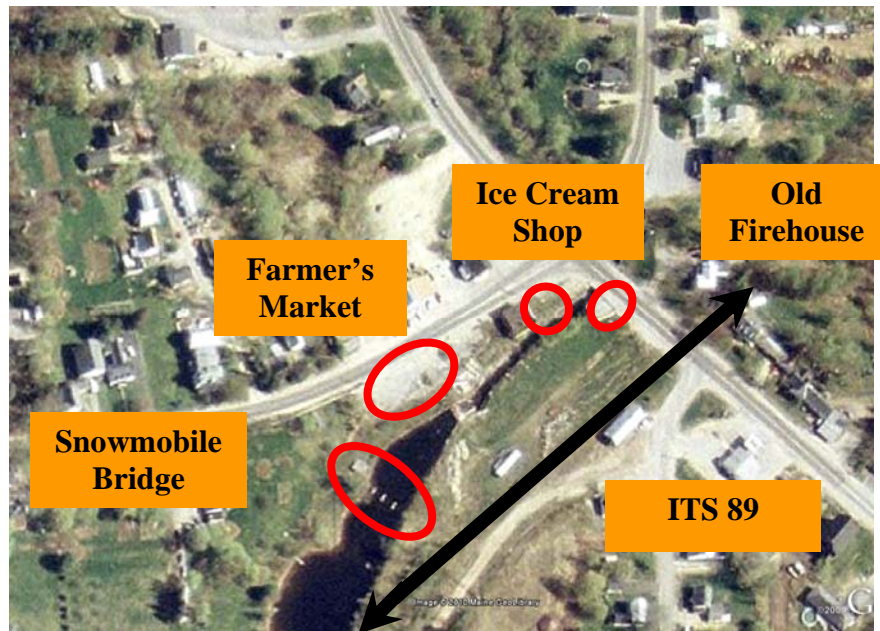


Figure 1: Town of Canton, ME Overview with proposed buildings indicated.

History of Canton

Canton, Maine was originally settled by the Ansagunticook Indians who were wiped out by small pox. In the late 1700's, the land was given to soldiers for their services in the French and Indian War. It became incorporated as the town of Jay in 1795, while Maine was still considered to be a part of Massachusetts. Jay became known

as an agricultural town because of the rich soil and the nearby river and lake which could provide power to the town. Mills, factories and a railroad came to the town in the 1800s, and it became a place of commerce and tourism. This led to the Canton area splitting off from Jay the name of the central village area being changed to Hayford Mills, then Canton Mills, which was shortened to the current name- Canton. Since then, the town has not experienced much growth, but continues to remain rural. (2008 IQP)

Basic Snowmobiling Information and Design Considerations

The town of Canton, Maine is a popular destination for snowmobilers. ITS 89, a major state snowmobile route, crosses through town just at the edge of the downtown. A new bridge leading into the down town area could draw in tourists and customers for the local businesses. There are many factors that must be considered when designing this bridge, such as the expenses, usage and general snowmobiling laws. There are no speed limits for snowmobiles in Maine, so it is expected that people use common courtesy and slow down before bridges and respect other users (Maine Snowmobile Association 2009). This means that a functional bridge should be easily visible and well marked to avoid accidents. Funding for area snowmobile trails come from the fees that are required by the state to register your snow vehicle. Since 75 percent of the fees are spent on trail maintenance and improvements, this could be a possible source of funding for the bridge restoration project. (Maine Snowmobile Association, 2009) Another source of funding is the local businesses that would benefit from snowmobilers coming into downtown.

One of our objectives for designing this bridge is to make it adequate to the anticipated snowmobile traffic. There are many snow mobile clubs in the area, including one that is located in the town of Canton that would benefit from the bridge. The project team will get in contact with the Canton Hi Riders to discuss their views on what should be done.

An examination of similar bridge restoration projects showed that in many cases it is less expensive to start with a completely new bridge, including supports. Depending on the condition of the supports over the river in Canton, this may be a possibility that we will investigate in our design process. The bridges examined were mainly designed from steel and timber and were designed for a weight load of 12,000 lbs, and ranged in cost from \$50,000 to \$75,000 with design and construction costs. These bridges ranged in length from 45 to 85 feet, similar to the one that will be built in Canton (Snowmobile Restoration, 2008).

Farmer's Market

There are two open lots currently in the center of town that are owned by the town. These two parcels could be developed and used by businesses that would help draw more people to the town, as well as allowing the present citizens to be able to fulfill needs without having to travel outside of their hometown. One of the structures being considered could be used to house craft fairs and flea markets. This building would draw visitors in from other towns and perhaps encourage tourists to stop on their way through Canton.

In designing the farmer's market, the functionality of the building as well as what it will be mainly used for will determine the design choices. Things such as safety, price,

and maximizing the space are going to be vital in the success of the building (Hacker, 2009).

The Old Fire House

Presently, there is an old firehouse in Canton, ME which is vacant and in very poor structural condition. In its decrepit state, it is not helping the economic growth of the town because it has no function and is an eyesore located in a prominent area of town. There are two options as to how this historic brick building can be renovated. It can either be restored by framing the interior and keeping the existing walls in place, or it can be torn down and rebuilt. Due to its age and historic value to the town, the preferable solution might be to keep the exterior looking the same. The only difficulty with this option is that it may not be the most cost effective way to complete the project (Wallender, 2009).

If the building is to be renovated, certain aspects must be taken into consideration. Depending upon how structurally safe the windows, walls, and roof are; they may still be salvageable. Things such as plumbing and electricity will need to be brought up to code so that the building will pass inspection. If this can successfully be accomplished, then the old firehouse can be transformed into a diner with a small efficiency apartment on the second floor.

Ice Cream Shop

The 25 foot by 30 foot lot next to the proposed warehouse could be developed and use as an two story building with the first floor reserved for businesses and the second for a small two bedroom apartment. The desired businesses for this location are an ice cream shop and a laundromat. The ice cream shop would draw customers and tourists into the

downtown area in the summer, and the laundromat would provide a place for apartment dwellers in the downtown area, as well as nearby campers and vacationers to wash their clothes. A wood structure would be the least expensive option and would blend in well with the rest of the buildings in downtown Canton.

Methodology

This project develops preliminary designs of a snowmobile bridge, firehouse, and two small commercial buildings on the two currently vacant lots. The construction of these facilities would bring more visitors into the town of Canton, Maine and give residents more local amenities as well as provide some jobs. In order to fully accomplish the designs for these four structures, we must follow specific steps which we have outlined in our methodology.

Design of Snowmobile Bridge

One component of our project is to reconstruct a snowmobile bridge crossing into the downtown area of Canton. To construct an effective and safe bridge, many steps must be taken prior to construction. First, an analysis of traffic and usage of the bridge must be created, along with typical snow loads to determine what kind of loading the bridge must be able to withstand. This was done by discussing with the Canton snowmobile club the usage, and looking up local snow load indexes and building codes for such bridges. A two lane design is necessary because of the volumes of traffic coming in and out of the downtown area, as the bridge connects to one of the major snowmobile “highways” in the area, ITS 89 (figure 2).



Figure 2: ITS Snowmobile Trail in the vicinity of Canton, Maine.

Types of materials were originally investigated to determine which types of designs and materials are most effective for this type of bridge construction. Steel, timber and concrete, among other types of materials were investigated in different designs for safety and cost effectiveness.

During the October visit to Canton, Maine, a meeting with the Snowmobile club in the area revealed that an older bridge from another stream was under consideration to be moved to cross the river across the existing concrete pilings. This existing bridge was 48 feet long and would need to be added to and analyzed before a decision could be made, to determine whether this bridge could safely be placed in this new location. The snowmobile bridge must be able to support the largest groomers, pictured below, which weigh up to 7,000 lbs with their equipment.



Figure 3: Truck Converted into a Snowmobile Trail Groomer.



Figure 4: View of an unused bridge which might be recycled to the new location

Figure 4 shows a photograph of the bridge that could be moved to the new location across the concrete piers in the below photograph. This bridge currently runs across a different part of the snowmobile trail and would be moved on the back of a truck to the new location. The truss part of this bridge would be removed, and a railing would be added to the base which would be secured to the existing concrete piers. An additional section of

bridge using the same dimension lumber will be added to the existing one to complete its span.



Figure 5: Dam Where Proposed Bridge Will be Located

The existing bridge is a truss with 2x6 boards running across it laterally and 2x12s with plywood reinforcements running as girders through the length of it. The base of the bridge has a width of 9' 6" and is wide enough to allow for two snowmobiles to cross in opposing directions, or for the largest grooming trucks to work on the path. This is the most cost effective option and an analysis using hand calculations and the computer program RISA 2D was used to determine if the deflections and stresses in each member were acceptable.



Figure 6: View of Proposed Bridge for Reuse

Afterward, a model was created in Revit, which allowed the quantities of wood used to be exported, as well as a 3 dimensional design which accurately depicted the existing bridge. This design was then imported into Google SketchUp and Google Earth so that how it looked across the river could be seen.

Building Locations Plan for Downtown Canton

The following map illustrates the locations of the building lots for our project. The different lots in the downtown area are highlighted and numbered. The ice cream shop will be located on lot number 39, the warehouse on 41, and the firehouse on the corner of 37. The bridge is shown below as a yellow line crossing between lots 37 and 41. The red lines indicate required setbacks based on Maine’s zoning regulations. (2009 IQP)



Figure 7: Overview of Buildable Area.

Design for Restoration of Firehouse

After visiting Canton and speaking with Professor Ray and other town residents such as the president of the Hi Riders, the local snowmobile club, it was determined that the existing shell of the firehouse structure could be salvaged and a small diner would be the business best suited for the first floor. The interior of the building is empty, and other buildings which were in worse condition have also been restored to their former store fronts. A quality restaurant would draw residents and summer and winter tourists into town because there are no restaurants nearby on the snowmobile/ATV highway that are easily accessible. The restaurant could be firehouse themed, and keeping the original shell of the building would add character to the downtown area and maintain the small town feel.

In order to make the plans for this fire station easier to visualize, we will create Google SketchUp or Autodesk Civil 3D designs showing the building as we envision it to be after completion. Below is an example from the Google Warehouse (Google SketchUp 2009) of what we would like the design to resemble.



Figure 8: Firehouse SketchUp Drawing

The surveys we completed using GPS equipment can also be imported and used in this design. This will allow people to see our plans and also make it easier for them to understand where all of the costs will be distributed. A cost estimate will be prepared for the restoration of the firehouse. We will base our estimate on the structural repairs, and also speak to professionals to ensure that we are making accurate assumptions for prices of work and materials. It will also be important to compare the price of completely knocking down the structure and rebuilding it to the price of restoring it as it is now.

Our visit to Maine in October was very enlightening as to the condition of the firehouse that we were working with. The exterior of the firehouse is cracked in several places, but the foundation appears to be in decent working condition. The roof has caved in and needs to be replaced with a gabled roof that would allow for an efficiency apartment to be built on the second floor.



Figure 9: Current Firehouse Interior View

The photograph below illustrates the work that needs to be completed on the interior of the fire house, and the other illustrates the damage to the outside structure that needs to be fixed before the building is usable again.



Figure 10: Exterior Structural Damage to Firehouse

Design for Main Street: Lots 39 and 41

There are two lots in Canton that are currently not being utilized for anything. They would make a great addition to the town if they were to be built on and could potentially bring visitors in depending on what kind of buildings are placed on the land. We would like to design a farmer's market/craft market to go on one lot and on the other lot we could place an ice cream shop and laundromat as well as another small apartment.

Main St: Lot 41

The flea market and craft fair area would be a great way to bring outsiders into town. The way that business is working in Canton currently is that most of the residents must *leave* in order to get their basic needs. Adding this building would create the opposite effect by drawing people from surrounding towns. People would be coming from surrounding towns which would also increase the business in other areas of town.

Lot 41 in the downtown area of Canton currently has a foundation on the site that could be reused in constructing the new warehouse flea market building. This facility

could be made out of corrugated steel, with large garage doors opening to the outside, allowing for it to be closed and heated in the winter, and more of an open air style market in the summer months. The following Google SketchUp illustration is a sample of a similar style of multiuse building that could be added to the site. Since different tourist groups are attracted during the different seasons, there would be a year round flow of customers. The SketchUp drawings will help us to create a building that is aesthetically pleasing and enhances the town, but that will serve as a large open space.

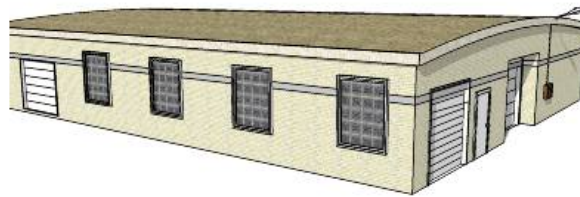


Figure 11: Potential Warehouse Design

In the above zoning plan (figure 11) the land that can possibly be constructed on in this lot is outlined in red within the cyan lot border. Between the red and the cyan lines is land that is too near the water front or other property to be zoned for a commercial building. There is about 48,000 square feet of buildable land on this lot and the large land available will be useful for both the building and fulfilling parking regulations (2009 IQP). Using current building codes, last years' site designs and survey results we will determine the best site layout and building design for this facility. We will also investigate the amount of traffic to the building because the amount of vendors

and customers using it on a regular basis will determine the square footage needed and therefore the parking lot size required.

Our visit to Canton, ME gave insight into the usability of this site for a warehouse. Currently, it borders Whitney Brook very closely on the back and Route 108 on the front side, with a small paved parking area already existing in the front. This unique placement means that the original foundation could be used by pouring a new slab over the existing one to avoid zoning complications, since buildings cannot currently be constructed that close to the river without special permitting. Below is a photograph of the site to be used with the foundation, which is approximately 65 feet by 35 feet, that previously existed.



Figure 12: Existing Slab in Lot

Main St: Lot 39

The ice cream shop and laundromat would allow for people to use facilities close to home. Anyone without the proper equipment to do laundry either has to travel to be able to do it, or buy washers and dryers. Since there are many seasonal camps around the lake without proper laundry facilities, a laundromat is thought to be a viable business. With the addition of more apartments to the center of Canton, it is even more imperative that a facility such as this is added to the area. By adding more apartments, they are also adding more affordable living for those who cannot afford to buy a house, or living in the center may be more convenient for certain people. The ice cream shop, although not a necessity, will bring in customers during the summer months and could also be used as a diner for times when it may be too cold. All of these additions will add to Canton's center and bring in more money to the town, as well as more visitors. A survey of the existing foundation, which was 25 feet by 30 feet, that will be used for the ice cream shop/laundromat building was conducted. The data will be imported to Autodesk Civil 3D for use in designing a building that corresponds with the location and existing foundation. This foundation was mostly covered by dirt and grass, but a new slab could be poured in the same area to ease problems with zoning regulations.

Results

Technology Overview

GPS Survey

Global Positioning System (GPS) is used by many different establishments to create extremely accurate topographical information. GPS is a new technology for surveyors that allows for an accuracy of +/- 1/2 inch. Upon our visit to the site, we used GPS equipment to get detailed information about the existing foundations so that we would know exactly what dimensions we should use in our design.

The following figure is a representation of the intersection abutting the lots that our main buildings are located on. These points, taken using GPS equipment and connected in a program called Sitework, can be linked to GIS systems such as Google Earth and can also be transferred into Google Sketch up or Autodesk programs to further design based on existing conditions. We will be able to use these coordinates to design the building and place it in its exact location in Google earth to see how it will look, and how the existing foundation will affect the building design.



Figure 13: Downtown Canton Survey Data

This is a visual aid showing the footprint that we will be using for the warehouse foundation when designing the new farmer's market.

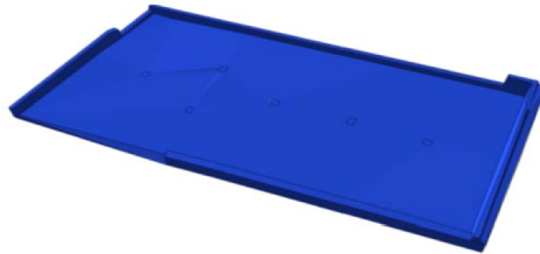


Figure 14: Warehouse Existing Foundation

The existing bridge piers will be reused, and in order to get completely accurate information to ensure that the bridge placed on the piers will be safe, we used GPS to determine the area of the top of the piers, their distances apart, and the depth to the water below.

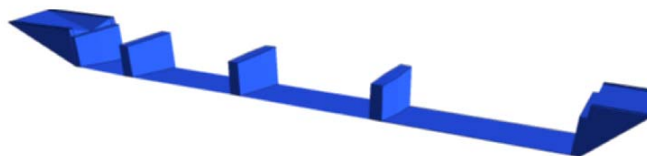


Figure 15: Existing Bridge Piers

AutoDesk Revit

AutoDesk Revit is a versatile program that allows for the design of structures using parametric object design so that a model that contains data about its materials can be created. Revit is divided into two different programs - Revit Architecture (RA) and Revit Structures (RS) but both use the same type of file- .rvt. The two programs can share files and contribute different things to the same design. RA allows for detailed architectural design of the building and site and offers many different material options for walls, floors and roofs that can be modified to most accurately reflect the actual design of the building.

Revit Structure allows structural items such as foundations, load bearing walls, columns, beams and girders. These items do not interfere with the architectural items that are selected, and can be connected to each other to form a structural design. This program can allow the whole structure to be examined through various 3D and 2D views. Floor plans with architectural details, structural plans, 3 dimensional renderings and exterior views are among those we used to design and view our structures. Since Revit creates Building Information Models, editing one view of the structure modifies that piece of it in every view, making it more efficient than AutoCAD drawings where multiple plans and views must be edited. Revit also contains information about all of the materials that are used in the project, and can create door, window, wall and structural schedules, which were very useful when we estimated costs of the various structures.

Since Revit is a part of AutoDesk, the points that were imported from our original on site survey can also be used to place the buildings accurately in Google Earth, or on the existing terrain in the area. These files could also be exported as .dwg files to Google SketchUp to be imported into Google earth.

Analytical Software

RISA3D

The first analytical software we attempted to use was RISA 3D. Since RISA is difficult to create detailed structures in, and Revit does not complete the calculations, we researched ways to combine the two programs. We found that both programs are compatible with each other and we could export the Revit files in the .dxf format, then import them into RISA. An outline of the structure will appear, complete with the loads that were added in Revit. This allows the structure to be analyzed and the performance of the elements of the structure to be calculated.

Unfortunately, after attempting this several times, we realized that although the structure itself would import into RISA none of the material properties were retained. Additionally, since our structure contained too many nodes and members, it was too large for the trial version of RISA 3D to solve.

ANSYS Workbench

After working with RISA3D, we tried using ANSYS, finite element analysis software that can be used in more complex forms and is fully available on campus. Revit files could be exported as .sat files and imported into ANSYS. Unlike RISA, ANSYS could import the full 3D model, and it appeared to look like the original Revit files, however once again, none of the material properties were maintained. The connections between joints were also not correctly imported into ANSYS, which made all of the analyses incorrect. Since there were so many connections, we decided to use a different program to analyze more basic trusses in the structure.

RISA 2D

RISA 2D was selected as the program to analyze slices of the building because of its simplicity and ability to complete many load combinations at once. We were able to draw the trusses and select the material, and all of the properties were preselected and maintained. RISA2D also allowed us to select the desired loadings for each type of load (Roof Live Load, Wind Load etc) and compiles and applies the ASCE loading combinations automatically to the structure. After they are solved for, it is possible to see deformations and results of each load combination, and it is simple to determine the most severe deflections, and whether or not they are acceptable for the structure.

Google Sketch Up and Civil3D

Rendered drawings are an integral part of this project, and two different programs are being considered to create models of the buildings and bridge that our project involves. Google Sketch Up and Civil 3D are both available on campus for the design and visualization of these structures and allow integration of the drawn models into actual terrain. SketchUp was released in 2000 and acquired by Google in 2006 and is free and available online. Since it was acquired by Google, it has been partnered with Google Earth, and allows for the importing of 3D renderings into Google Earth where they are available to all users. AutoCAD Civil 3D allows terrain to be imported from GIS data and creates more detailed drawings that can also be seen in their environments (AutoCAD Civil 3D, 2009). Though they are not visible to other users, it is a powerful program and allows for more detailed renderings than Google SketchUp.

The design of the building in down town Canton was created to fit in with the downtown architecture and to house both an apartment and some small businesses. A two story wood structure was selected so that the building would be similar to others in the

downtown area, and less expensive to construct. The building was modeled after the original one that stood on the cement slab foundation that is being reused for the new construction. The original downtown area is shown in the figure below, as it looked before it was damaged by floods and fires.



Figure 16: Historical Photo of Downtown Canton

First Design Attempt

The building was designed to incorporate two businesses on the first floor—an ice cream stand in the front, easily visible from the street, and a laundromat in the rear section accessible from a side entrance. The lot is the size of the existing foundation, 25 x 30 feet and abuts the river. The slab is in good enough condition that it can be reused, and is close enough to bedrock that no excavation is needed. The first design attempt was very simplistic and included the necessary services without much architectural detail. The material for structural construction was chosen to be CMU blocks with a brick exterior to match the restored hair salon and office building that was recently completed next door.



Figure 17: Rendering of the First Design of the Ice Cream Shop

The first floor was to include an ice cream parlor and laundromat with a storage area and restroom facilities, while the second floor housed a 2 bedroom, one bathroom apartment. The ice cream shop was designed to include indoor seating so that it could be open year round. As can be seen in Figure 18, the ice cream shop had space for both service and for customers to eat inside, as well as a restroom and storage closet. The side hallway housed the staircase to the second floor apartment as well as several washers and dryers.

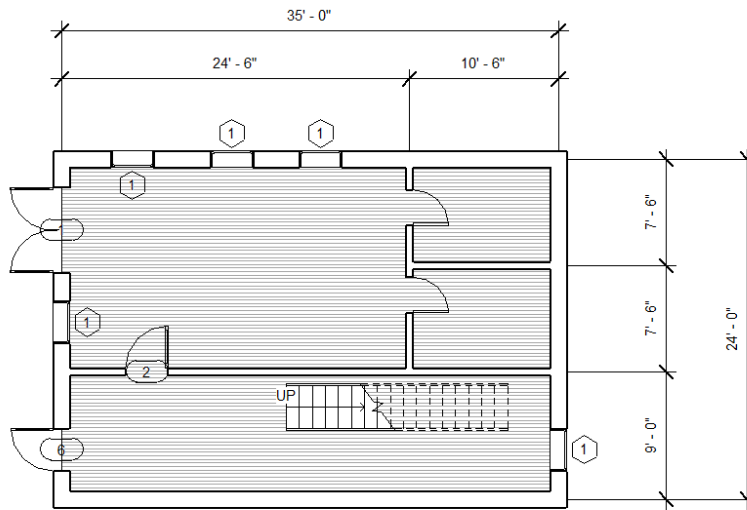


Figure 18: First Floor Plan of the First Ice Cream Shop Design

The second floor layout can be seen in 19, below. Two bedrooms are located on the left hand side of the drawing, and a bathroom on the upper right hand side. The remaining open area was to be used for an open kitchen, living and dining room area.

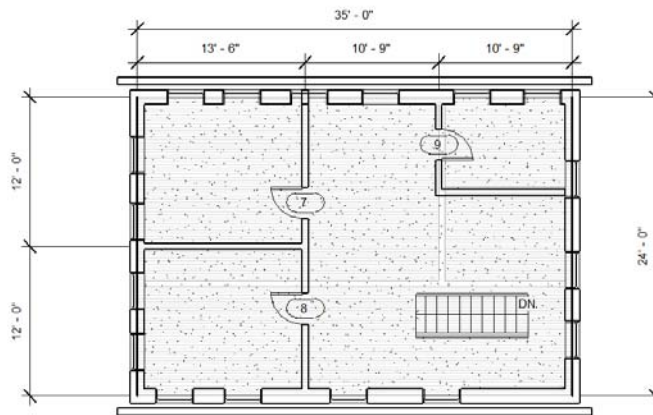


Figure 19: Second floor Plan of the First Design

The walls of the second floor were 5 feet on the pitched roof sides, and the ceiling in the middle was vaulted to a height of 10 feet. There was no use for attic space in this

building, since it would all be used by renters, so the ceiling would be insulated and supported by 2x12 rafters.

This design was revised to provide more space to the apartment renters, as well as to make the ice cream shop a seasonal facility and include more laundromat space.

Reconsidering Layout and Architectural Design

After examining the previously existing buildings, and the possible space constraints of the first design, a second iteration was created.



Figure 20: Exterior view of Ice Cream Shop

As can be seen in the rendering, the lower floor was made smaller, and a porch and window service area was created for the ice cream shop. The overhang of the second story was designed to mimic the previous version of the building that was destroyed by

the fire and floods along the river. A combination of trusses and rafters were used to create the roof structure with the gables.

The layout of the first floor can be seen below. The stairwell to the upstairs apartment will serve as the division between the ice cream shop and the laundromat. This design will allow employees to enter the store, and apartment dwellers to have easy access to the laundromat below. The ice cream shop will consist mainly of a service counter and storage space, with service windows where customers can buy their ice cream and a bathroom will be located in the rear of the laundromat. Only employees of the ice cream shop will be permitted to use it, since customers do not enter the shop.

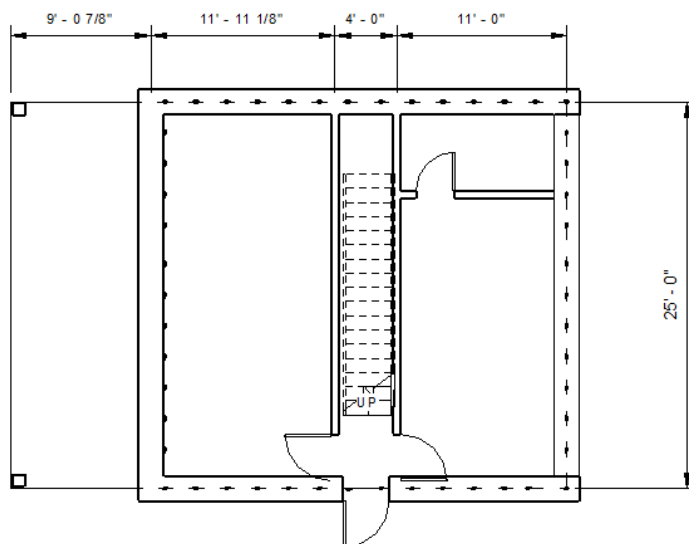


Figure 21: Final Design First Floor View

The second floor will house a 2 bedroom, one bathroom apartment with a gabled roof. The four peaks fall in line so that each bedroom will have vaulted ceilings, as well as the kitchen and dining/living room area. The lowest ceiling falls above the bathroom and the stairwell, and meets the wall at a height of 5 feet. The bedrooms are located in the rear

of the apartment and have views overlooking the river and fields behind it, which will allow for more privacy than if they faced the street. The living and dining area is large enough to house a dining room table as well as typical living room furniture.

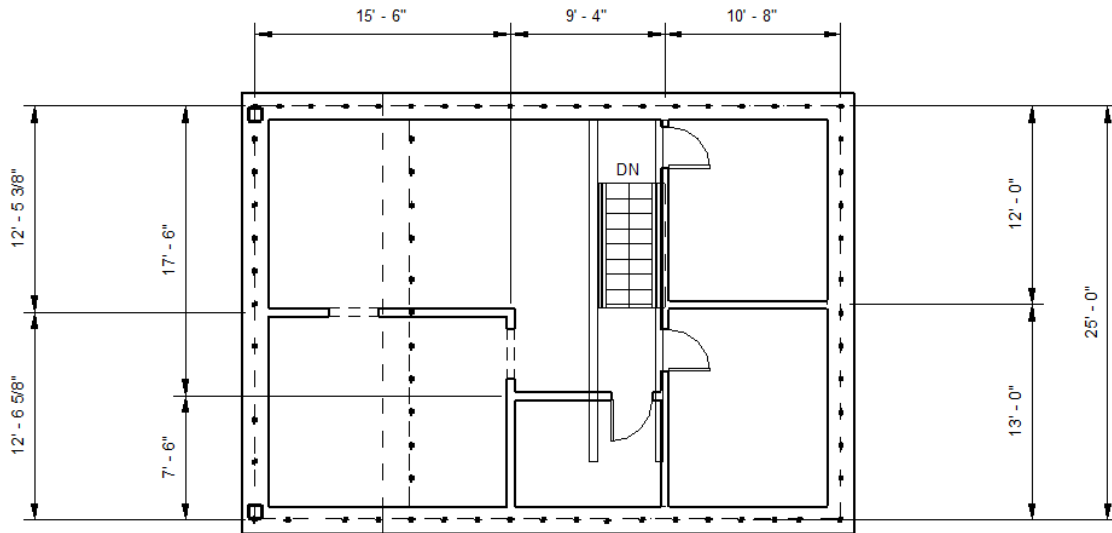


Figure 22: Second Floor Final Design

As can be seen in the above floor plan, stairwell leads directly into the living/ dining room area, as well as next to the first bedroom. The kitchen area is connected, as is a full bathroom. The second bedroom opens near the bathroom. The bedroom areas are 10'8" x 12' and 10'8" x 13' which will provide adequate space for furniture and storage.

Structural Design

This building is to be constructed out of wood, and framed with 2x4 pieces of wood as well as prefabricated Howe trusses that will form the gabled roof and allow for higher interior ceilings on the second floor. The trusses are to be placed 2 feet on center, as are the 2x4 studs inside the structural walls. The floor framing uses 2x6 foot girders which

are also located 2' on center spanning between the structural interior walls and the beams exterior studs.

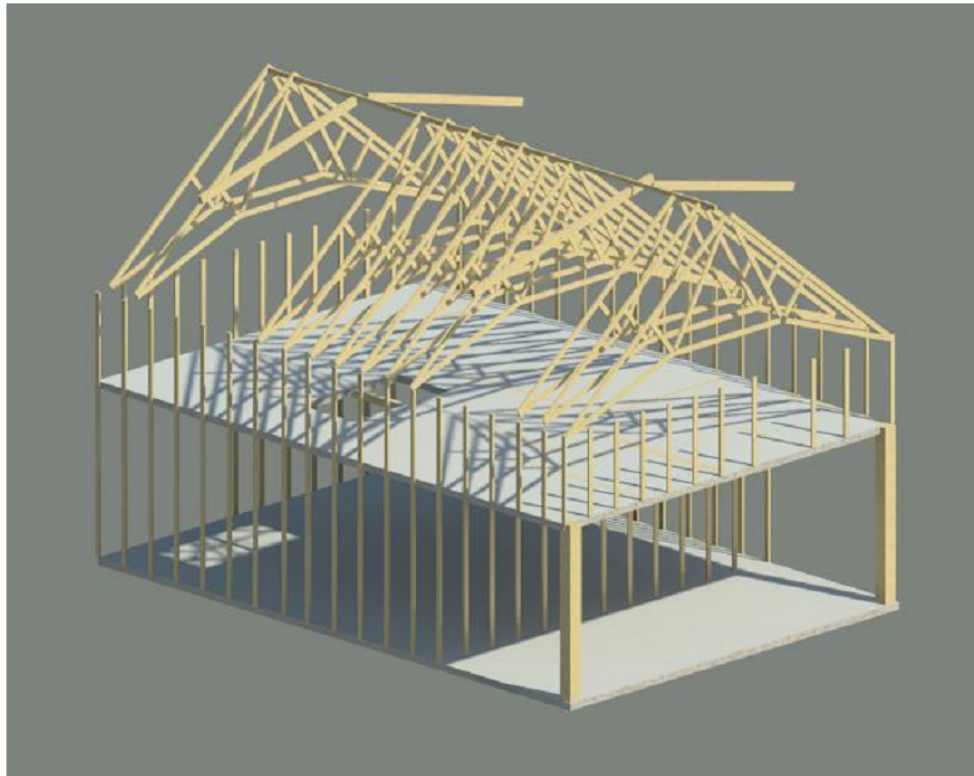


Figure 23: Structural Elements

Slices of this design were analyzed using the program RISA 2D using ASCE 2005 loading combinations. The loads were applied in accordance with these combinations and with the required loading (International Residential Code, 2000) for the uses and location.

Table 1: Loading Types

Load Type	PSF	PLF
Wind Load	12.7	25.4
Snow Load	90	180
Residential 2 nd Floor Live Load	20	40
Roof Live Load	20	40
Roof Dead Load	30	60

After these loads were applied the maximum deflections were found at each joint and in each member in the structure. The maximum joint deflections that were found are shown in the table below.

Table 2: Ice Cream Shop Joint Deflections

	X axis	Y Axis
MAX	0.031	0
MIN	-0.038	-0.102

The maximum deflection in each member is shown in the table below in inches. These deflections are acceptable since there is no access to the roof and the maximum deflections under snow will not be very noticeable to residents of the apartment.

Table 3: Ice Cream Shop Member Deflections

	X Direction	Y Direction
Max Deflection	0.078	1.202
Min Deflection	-0.106	-1.204

Under the worst case loading, the roof truss members only deflect -1.204 inches downward which is acceptable. The maximum allowable deflection is 1.25 inches since the span is 25 feet, using the L/240 standard equation (ASCE 2010).

Table 4: Ice Cream Shop Acceptable Deflections

Acceptable Deflection	Passes
1.2	

Cost Estimate

The costs for this construction project were estimated using the average costs for typical residential construction costs based on material and labor. (Ogershok, 2008) Revit Architecture and Revit Structure allow for the exportation of schedules of material, which

allows you to review information about all of the building supplies that will be used in construction. Once these quantities are determined, the unit cost can be applied, and the total cost estimate calculated.

Table 5: Cost Estimate of Ice Cream Shop

Category	Cost
Structural	\$14423.12
Flooring	\$6654.70
Ceiling	\$4770.88
Roofing	\$18000.00
Doors and Windows	\$6477.60
Walls	\$10361.62
Electric	\$16967.48
Plumbing	\$8309.00
Stairs	\$2800.00
Total	\$85964.40

The cost of structural framing includes all structural work, from the prefabricated trusses to the labor required to place all of the wood structures. Structural and stud grade lumber is used based on the use of the wood, and plywood is used for subfloor construction as well as a base for exterior walls. The flooring costs are based on finishing the slab on grade basement as well as the plywood subfloor on the second floor. Linoleum tiles will be laid over the slab on the first floor in both the laundromat and ice cream shop as it is easy to clean and inexpensive. The apartment will have hardwood flooring since it lasts a long time and is easy to clean and maintain. The ceilings will be

hung gypsum board on both floors. The second floor, due to the unusual ceiling design is more expensive to insulate and cover, but since the design allows for extra height and less wasted space between the ceiling and the roof, it is worth the cost.

The cost of the exterior walls includes the insulation, the interior gypsum board and the exterior siding of the building. The wiring and plumbing costs, as well as the furnace are based on typical residential costs for two story buildings of the same square footage.

Since no foundation or site work is required for this project it is less expensive than comparable construction would be on a site that did require such work.

Warehouse Design

First Design Attempt

To begin designing the warehouse for Canton, we first tried to use the program RISA3D. After RISA3D failed to work, we began using Revit Architecture and Structural. From our visit to the site where the warehouse would be located, we knew that we would have to keep the dimensions the same as those of the original warehouse foundation. As previously discussed, we used GPS surveying to get dimensions of the existing foundation and used those dimensions, which are precise within +/- 1/2 inch, to create our model. We knew that this space would be used for craft fairs, farmer's markets, and flea markets so we wanted to use garage doors to enable people to open the building up in the summer, but also have the option of closing it during the winter and using another entrance (i.e., see figure 24). We also wanted to keep the interior as one large space to accommodate a flea market/farmer's market function.

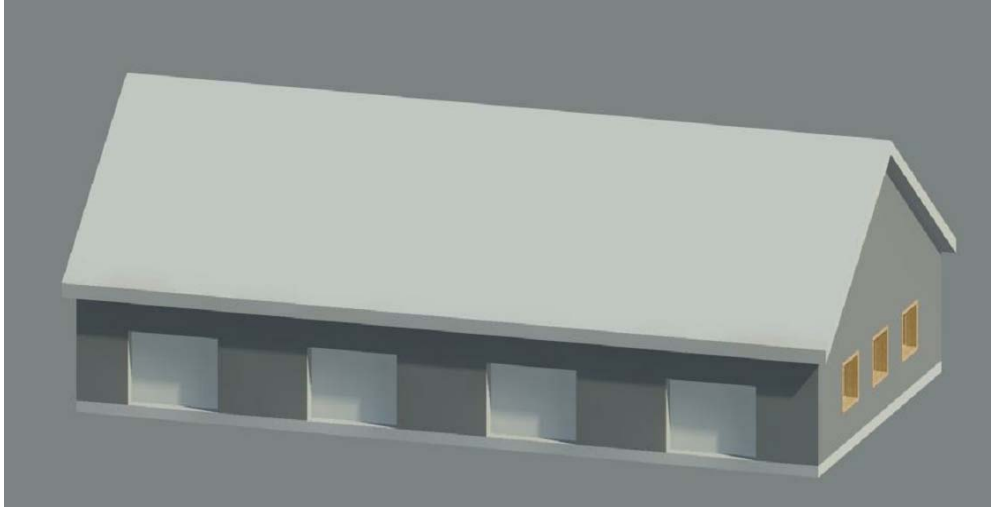


Figure 24: Architectural Warehouse Rendering

We also wanted to put in as many windows as possible so that the lighting would be natural and require less artificial lighting (see figure 25). Also, the view to the water down below would be attractive and we did not want to close the building off so that this area would not be visible.

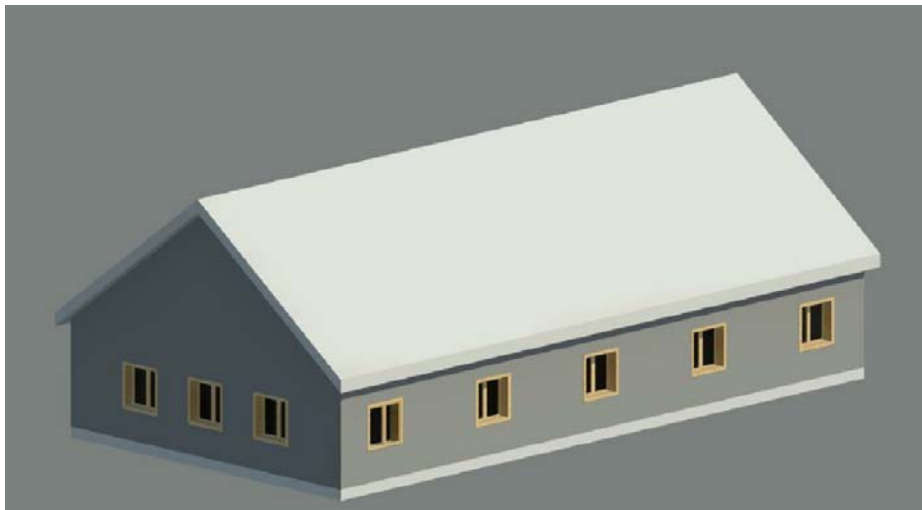


Figure 25: Back of Warehouse

After creating a general outline for the architectural aspects of the warehouse, we were then able to link the Structural and Architectural files together to begin creating structural drawing for the warehouse (see figure 26).

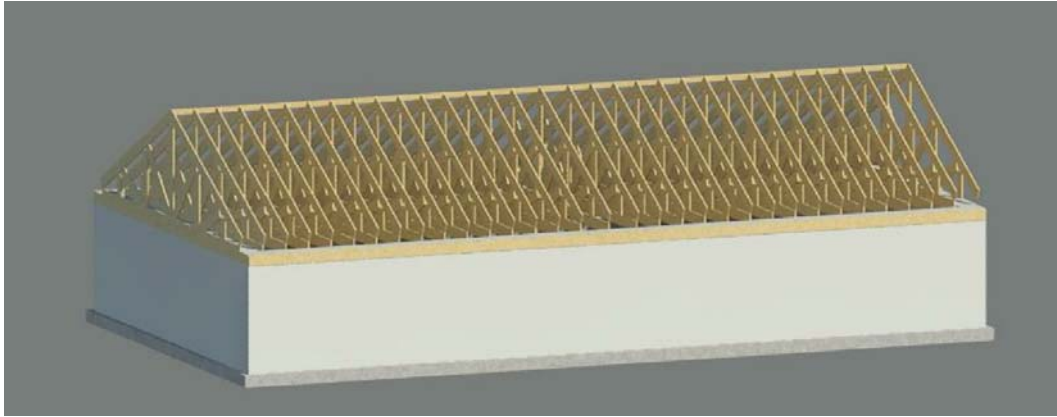


Figure 26: Structural View of Warehouse

The first design that we explored used a concrete masonry unit (CMU) structural wall with insulation to help keep the heat in the building. We then added Howe Gabled 6-panel trusses 24” on center consisting of 2x12 dimension lumber. Finally, we put a column in the center of the design to help distribute some of the loading from the roof to the foundation.

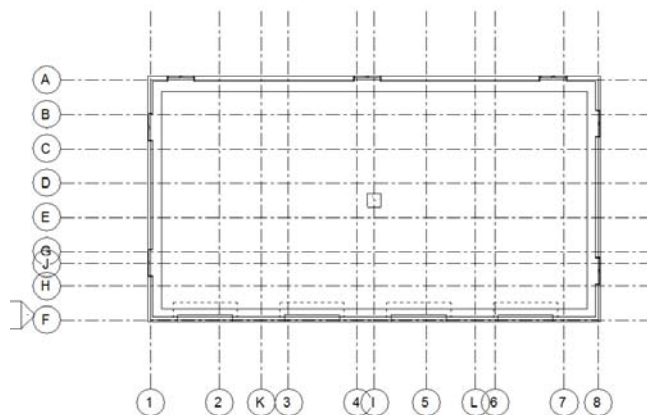


Figure 27: Floor Plan

Reconsidering Layout and Architectural Design

We reviewed the designs more thoroughly and realized that by using CMU structural walls and 2x12 dimension lumber, we were overdesigning the structure and also that the cost could be lowered by construction the building solely out of wood. We then created a Revit model to reflect our new design, which consists of 2x6 dimensional lumber and wooden shingle siding, no CMU walls, and no center column. Shown below is the 3-D structural view of the Revit model (see figure 28)

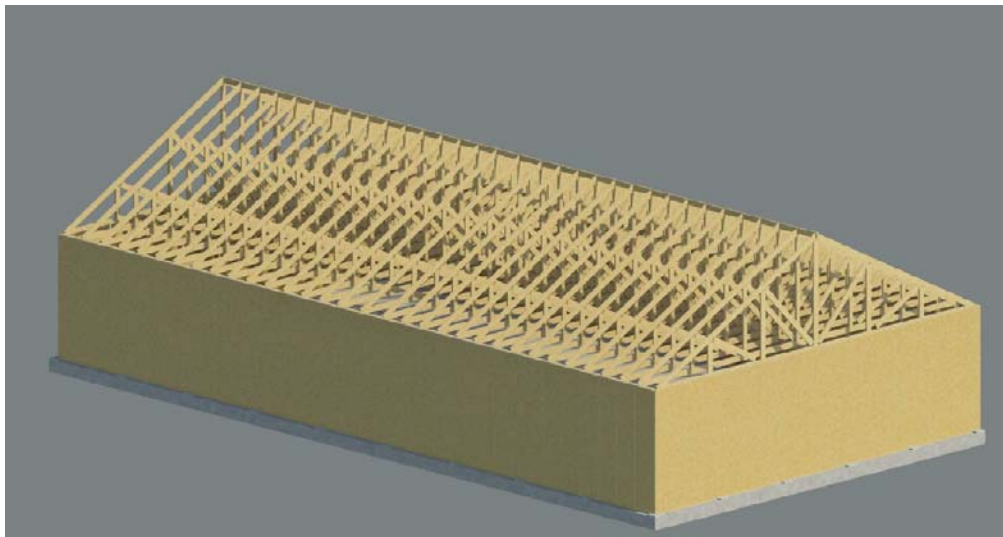


Figure 28: Wood Warehouse Revit Model

Figure 29 shows another rendered structural view of the warehouse with the exterior plywood hidden to make the 2x6 wall studs more visible.

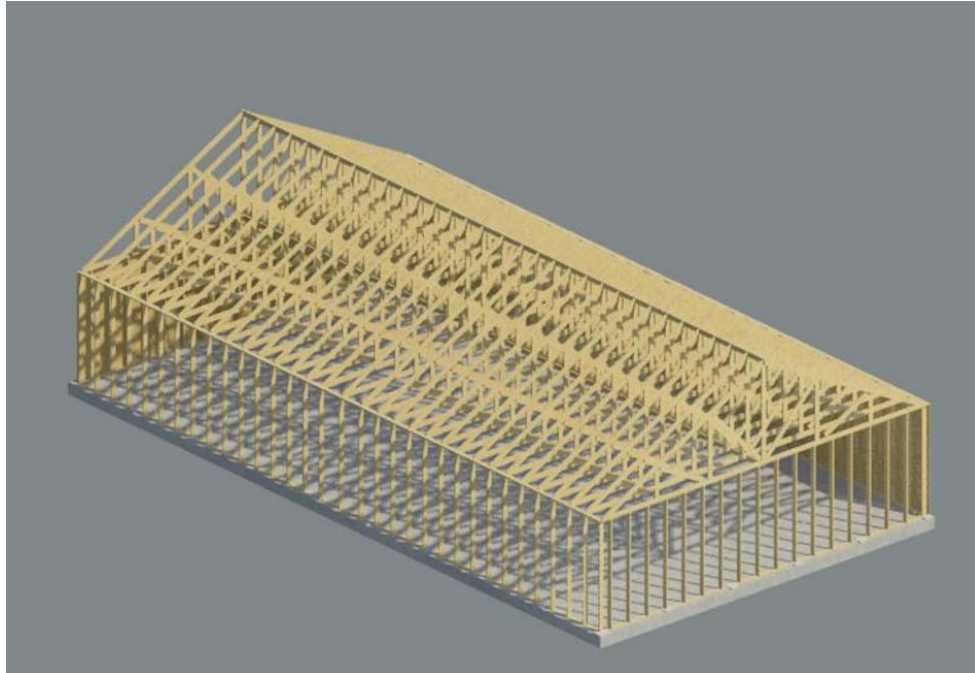


Figure 29: View 2 of Warehouse

The columns are also 2x6 dimensional lumber. After redrawing the Revit file, it was then ready to be exported to a structural program.

Structural Analysis of Warehouse

After we finished creating a potential structural plan, we worked on getting the Structural file imported into RISA3D. The file created in Revit Structural can easily be imported into RISA, but our license does not allow us analyze structures with as many members as were in the warehouse design, so we redrew cross sections to be used in RISA2D.

The next step is to determine if this design was adequate based on the anticipated loadings, and if it is not, we will begin increasing the size of the elements involved in the design.

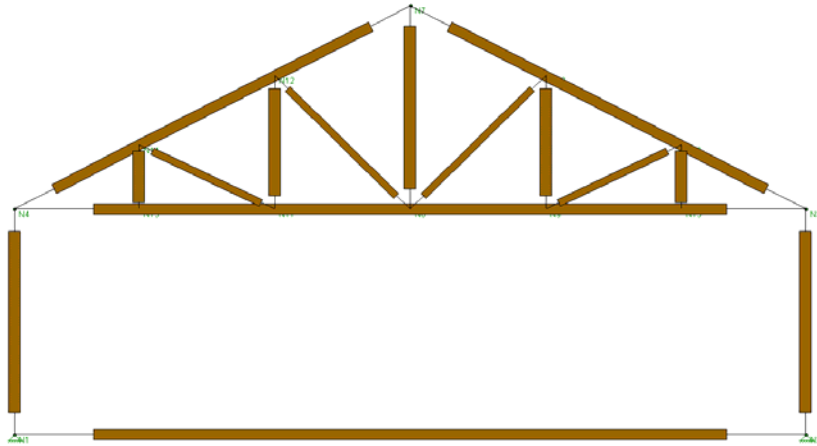


Figure 30: RISA Warehouse File

The cross section was tested using the loads shown below and was evaluated for all ASD 2005 loading combinations. (International Residential Code 2000)

Table 6: Warehouse Loading Conditions

Loading Conditions	Loading (lb/f)
Wind Load	41.4
Roof Live Load	40
Snow Load	180
Dead Load	13.4


This loading combination carried out in RISA2D produced information for each of the ASCE loading combinations. After exporting the joint deflection information into Excel, the results were as follows.

Table 7: Warehouse Joint Deflection Information

	X-Direction (inches)	Y-Direction (inches)
Limiting Value	.163	-.396

The span of the truss is thirty five feet so the deflection limitation is based off of the equation length (inches)/240 (ASCE 2010). The result of that calculation is that the allowable deflection is 1.75 inches which is significantly lower than the deflections expected by the structure with the above loading.

Table 8: Warehouse Acceptable Deflections

Acceptable Deflection (inches)	Passes
1.75	

Cost of Warehouse

The cost of the warehouse was a big factor in determining how it would look. Considering that we are not going to be pouring a slab because we will be using the existing slab, and that we altered the warehouse to contain all wood, the cost was brought down significantly. The people in the town of Canton wanted to be able to build these structures for fairly low costs and potentially by hand, so this was also an important factor.

Although we wanted the lowest cost, we also wanted to make sure the buildings fit in with those existing in the area. To do so, we checked two different pricing options. The first would be with a brick exterior (to match the other buildings) and the second would be with wood siding. The breakdown of costs, which was obtained using RS Means (Waier, 2009), is shown below.

Table 9: Cost Analysis for Warehouse

	Brick (cost/sqft)	Wood (cost/sqft)
Shell	\$40.00	\$25.00
Interiors	\$10.00	\$10.00
Services	\$13.00	\$10.00
Fees	\$34.00	\$17.00
Total	\$97.00	\$62.00

After looking at the breakdown, it is evident that although brick would look nice and match some of the other nearby existing buildings, if the town wants to build the area up all at once for the least amount of money, wood is the best option. Using a unit cost of \$62.00 per square foot and the floor area of 2275 square-feet, the total cost of the structure built on the existing foundation is \$141,050. This is not extremely expensive, and would bring many people into the town, so it would definitely be worth it!

Restored Firehouse

Design Attempt

The firehouse needed to be used as a small restaurant as well as an apartment. In order to accomplish this, we decided to make a large open area closest to the street because the street runs along the left side of the picture in figure 31. There is a bathroom in the restaurant area for guests, and the staircase for the apartment leaser to use runs along the side of the building so that they can park in the open area next to the parking lot which will hopefully be a parking lot in the future!

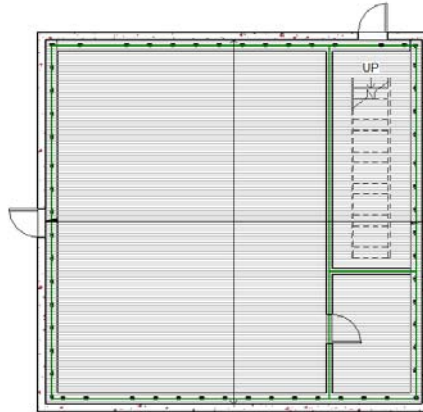


Figure 31: Level 1 Firehouse

This is the second floor of the firehouse building (see figure 32). The living area for the house is located at the area marked “1”. There are two bedrooms which could be used for a single person with an office, or could be rented out for two people. The bedrooms are located at number 2 and 3 and are about 120 square feet each. The bathroom is in the bottom right at number 4. By doing this, we are able to keep the firehouse in the same location and continue to use the existing walls, but add 2x4 structural framing on the interior because the exterior is not in a condition to hold loading.

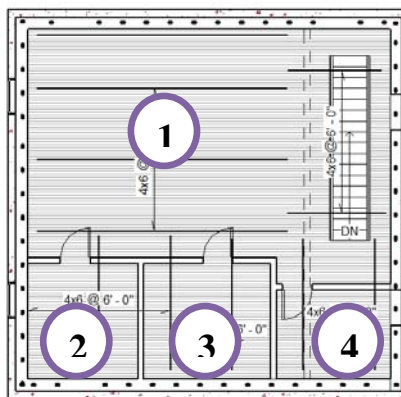


Figure 32: Level 2 Firehouse

The figure shown below is what we expect the firehouse to look like after renovation. It will be more aesthetically pleasing, which is important because it is on the main road in the center of Canton. It will keep the same feel as the old firehouse, and take advantage of what is currently wasted space. This will allow for the center to bring in more money.



Figure 33: 3D Firehouse View

Structural Analysis

In order to make sure that these designs were possible, we took a cross section and analyzed it in RISA2D. The picture below shows some of the structural elements of the firehouse. We are leaving the exterior walls, so the only thing that we will be adding are interior walls and structural elements to ensure that the interior is able to withstand its own weight.

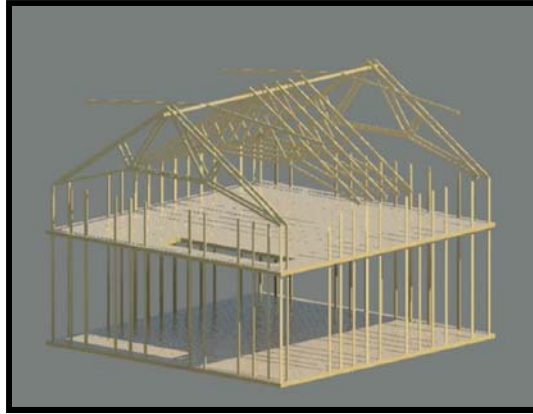


Figure 34: 3D Structural Firehouse

The figure below shows the cross sectional view of the firehouse that was used in the structural analysis.

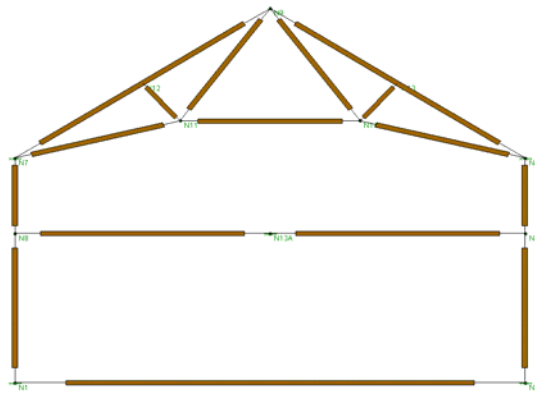


Figure 35: RISA wireframe of Firehouse

The loading situations (International Residential Code, 2000) are the same as were used in the warehouse, but there is another consideration which was also used in the ice cream shop. The building has two stories, so the dead load and live load of the second floor must be tested also.

Table 10: Loading Conditions for Firehouse

Loading Conditions	Loading (lb/f)
Wind Load	41.4
Roof Live Load	40
Snow Load	180
Live Load (2 nd Floor)	40
Dead Load	13.4


The values below are the deflections created using this scenario. The loading conditions are all based off of ASD 2005 load combinations. (ASCE 2010).

Table 11: Limiting Deflections for Firehouse

	X-Direction (inches)	Y-Direction (inches)
Limiting Value	.06	-.238

These are acceptable based on the equation of maximum allowable deflection length (inches)/240. (ASCE 2010) The maximum deflection occurred in the center of the roof truss which was expected. Although there are some minor deflections, none are as large as the calculated value of 1.7 inches.

Table 12: Acceptable Deflection of Firehouse

Acceptable Deflection (inches)	Passes
1.7	

Cost of Firehouse

Calculating the cost of the firehouse was done slightly different than all of the other buildings. There is an existing brick wall on the exterior so it is not necessary to consider the cost of shingles for the building. We do not need a foundation because that is also already poured. The rest of the building cost calculation was similar to that of the others and was done with using RS Means. (Ogershok, 2008)

Table 13: Firehouse Cost Breakdown

	Interior Framing
Shell	\$20.45
Interiors	\$12.34
Services	\$12.04
Fees	\$25.00
Total	\$69.83

The total area of the building is 1122 square feet per floor, and it has two floors so it has a total of 2244 square feet. This would work out to a total of \$156,698.50 for the project including the contractor and architectural fees. If the work were to be done by the residents and not subbed out, then the project would be closer to \$100,000 and it would be fairly reasonable to complete for the town's budget. Furthermore, it would be a great addition to the center of Canton.

Bridge Design

In order to evaluate the bridge, we first did hand calculations. The calculations consisted of checking loading situations to ensure that the bridge that is already built can be used across the existing piers. Below is an AutoCAD representation of the existing bridge.

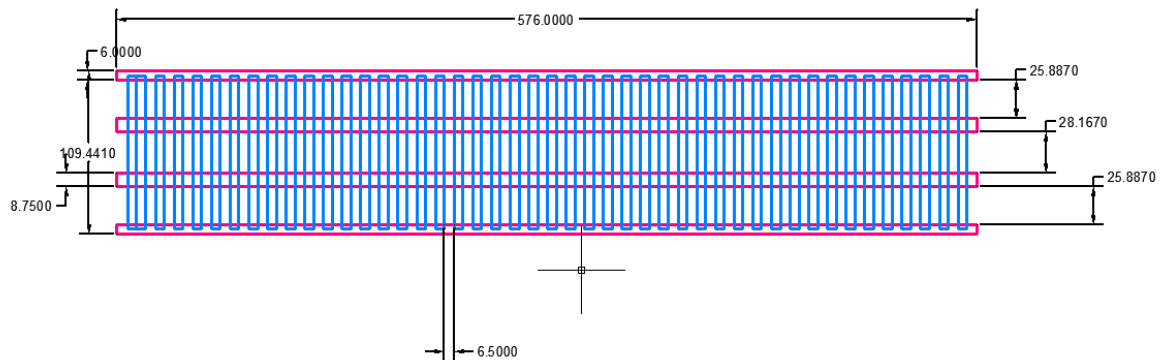


Figure 36: Bridge Dimensions

Once the AutoCAD file was created with accurate dimensions, it was imported into Revit Structures, where the bridge was constructed using structural members from the program, and the CAD file as a template. Figure 37 shows a top view of the bridge Revit file. Hand rails (required for the bridge) were added to replace the truss that will be removed when the bridge is transported.

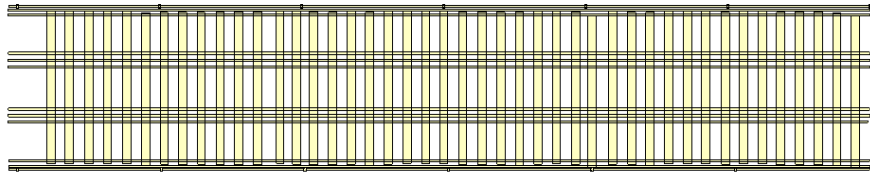


Figure 37: Bridge Design Based off CAD File

The rendered design can be seen below in Figure 38, as it will look when placed across the preexisting concrete columns. The wood quantities and schedule were exported from Revit so a cost model of a new bridge could be completed.

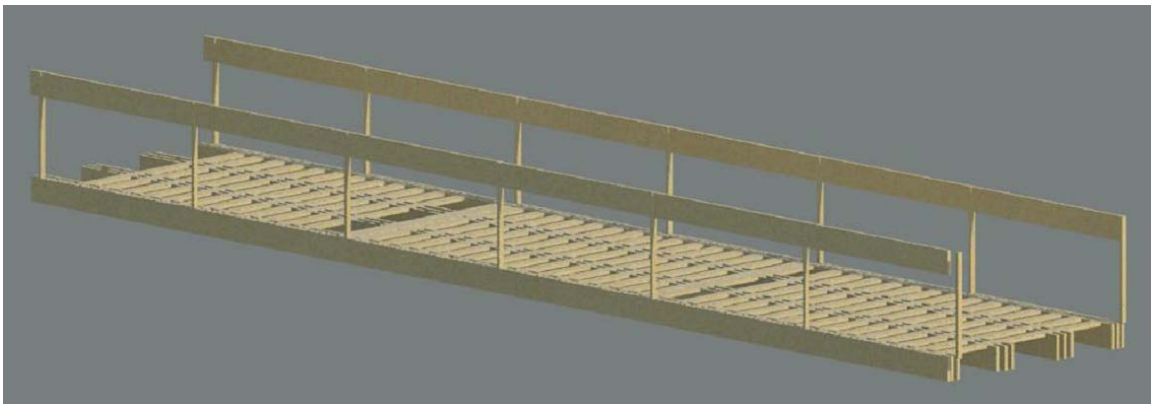


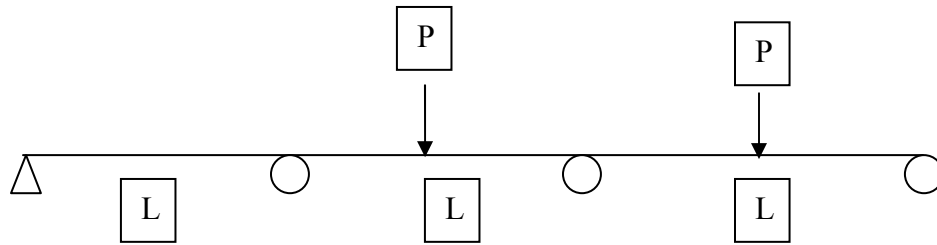
Figure 38: Revit Bridge Model

Bridge Structural Calculations

Hand Calculations

In order to determine whether the snowmobile bridge currently crossing Whitney Brook at another location could even be considered for use in the downtown location near the dam, rough hand calculations had to be completed. These preliminary calculations

examined a worst case scenario over the widest spans to see if the bridge could resist the moment caused by two snowmobile groomers placed in the middle of each of the spans. Each of the spans (represented by the variable L) was estimated to be 26 feet, and the weight of each groomer was estimated to be 7000 lbs. The 7000 lbs would be divided by the four girders, meaning that each would receive a downward force (P) of 1750 lbs.



These calculations are repeated for the beams spanning the width of the bridge, which are placed every three feet, and support the same 1750 lb loading as the girders. According to chapter 3-22c of the AISC handbook, the multiplication factor to determine the moment in a beam supported like the one above, for the maximum moment was 0.187 in the center of the beam. This resulted in a moment of 47,124 inch lbs in the girders and a maximum moment of 11,781 inch lbs in the three foot planks.

The maximum stress in each beam and girder was determined using the equation $MC/I=\sigma$, where M stands for the maximum moment, C is half the height of the beam and I (moment of inertia) is equal to $(base*height^3)/12$ for each of the planks. Because the girders were comprised of both 2x12 pieces of lumber with plywood sandwiched between, we only included the strength of the timber, because the properties of the plywood used were unknown. This allowed us to triple the moment of inertia for a typical 2x12 piece of lumber and use that as our given value.

RISA2D Calculations

Once the design of the bridge and loads were finalized, RISA 2D was used to create a basic analysis of the structure using typical loads. The girders were analyzed by applying the 90 plf snow load, as well as a 13.1 plf dead load and two point loads of 3500 lbs to the 23 foot spans between the pre existing concrete columns. ASCE 2005 Strength standard load combinations were used to determine the deflection of each piece of the structure.

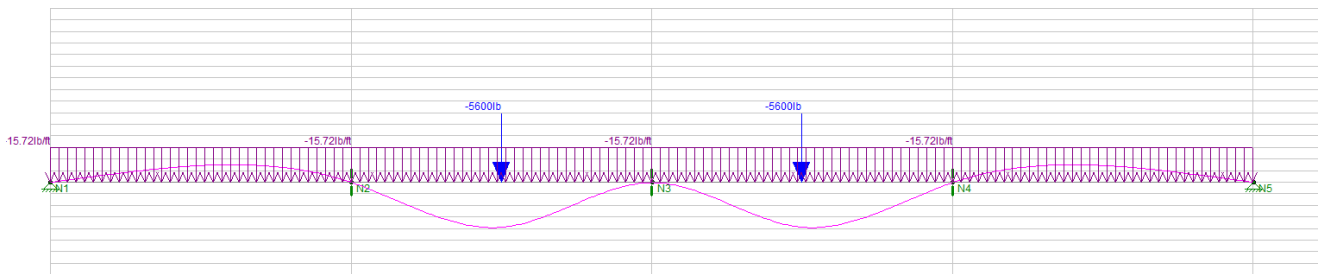


Figure 39: Maximum Loading Combination with Deflection

Figure 39 shows the deflections on each section of the bridge girders with the maximum loading combinations. In the figure, the deflection is multiplied by a factor of 40 so that it is more easily visible. The actual deflection for this load is 1.05 inches, which is less than the allowable deflection of 1.15 inches. (Allowable deflection = length of section / 240) (ASCE 2010) The girders on this bridge are acceptable according to these calculations and will support the weight of the groomers, as well as snow.

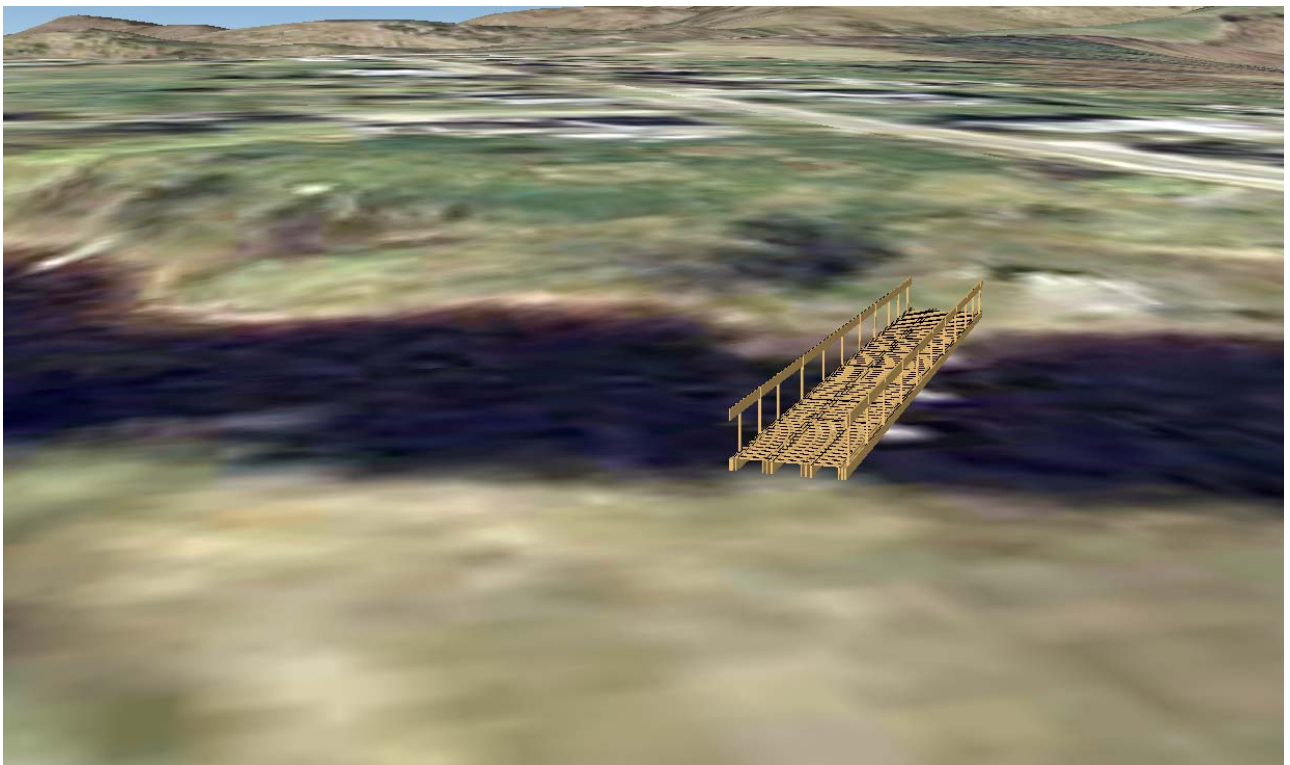
Table 14: Acceptable Deflections for Bridge

Acceptable Deflection (inches)	Passes
1.15	●

These calculations are based on new material, and the wood used is Douglas Fir Larch. Since the bridge has already been used and the material has been deformed, the bridge may not be capable of supporting the loads we have calculated.

Google Earth Placement

Once the design and calculations for this bridge were completed, the final Revit drawing was imported into Google Earth. It was placed in its proposed location, crossing the river on the concrete pilings that currently exist.



Cost Estimate

The cost of the extension of the bridge is estimated for typical wood construction for the additional 23 feet that would need to be connected to the original bridge construction. If the entire bridge were to be reconstructed, the cost would be much higher, and is also estimated at the same rate. This does not include the price of transporting the original bridge into place, since the exact method is unknown.

Table 15: Bridge Cost Analysis

	Materials	Labor	Total
Final Section	\$806.50	\$2070.00	\$2876.50
Entire Bridge Reconstruction	\$3226.00	\$8280.00	\$11,506.00

Google SketchUp and Google Earth

Google SketchUp and Google Earth are very valuable tools that help create images that depict what the streetscape of downtown Canton will look like with the proposed construction projects. We found several ways to bring our designs from Revit into Google Earth. The first method we attempted was to export the Revit designs as .dwg files and to import them into AutoDesk Civil3D. Civil3D has an option to publish the drawings to Google Earth at a specified latitude and longitude. The buildings that were imported were distorted, however and appeared in inaccurate colors and the location was not always exact. Another problem with this was that only one picture could be imported per file, so a full streetscape could not be viewed.

Google SketchUp was then used to import the .dwg files for each of the structures where they could be modified in color then placed in the correct location on the streetscape. Once imported into Google SketchUp, the buildings could be exploded, meaning broken down into components, so that they could be colored and textured differently. Multiple structures could be placed in the same file, which made the full street view available. As can be seen in the figure below, the structures were added to the terrain in Google Earth in their proposed locations. From left to right the buildings are the renovated fire house, the proposed ice cream shop, an existing building owned by Professor Ray and the proposed warehouse.

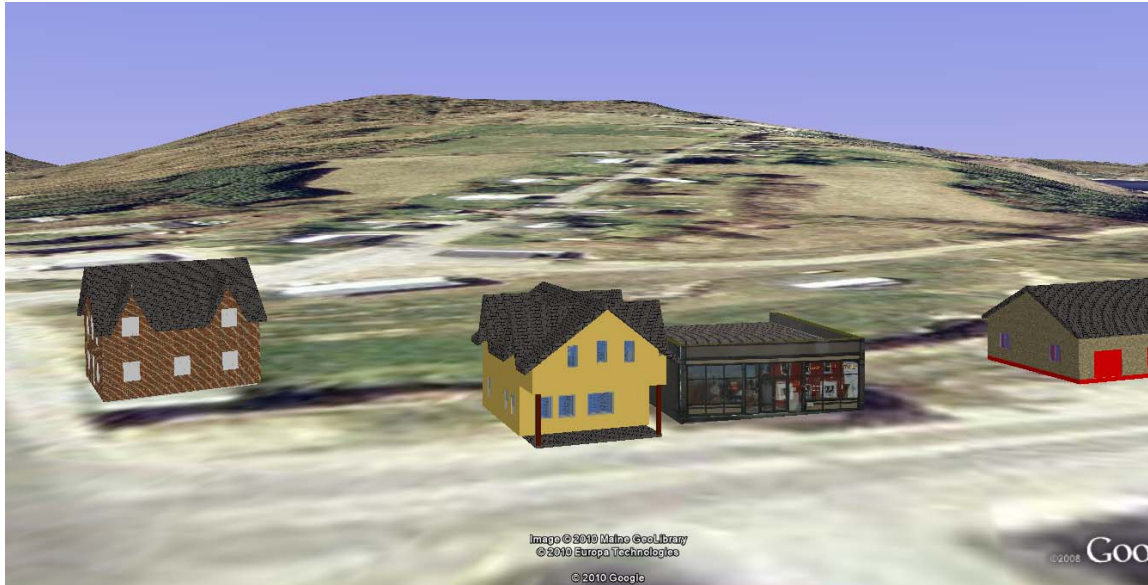


Figure 40: Proposed and Existing Construction in Google Earth

Figures 41 and 42 show all of the proposed construction for our project, including a snowmobile bridge to the right of the warehouse. This view allows the viewer to see how the new buildings will fit in with the current physical landscape as well as the building footprints that come from the Google Earth satellite images. Since the terrain is three dimensional, like the SketchUp objects, it provides a more accurate view of what the new landscape will look like.



Figure 41: Google Earth Full View of Downtown with New Construction



Figure 42: View from Rt 140 of Downtown Canton

A view of the buildings as foot prints can also be created by zooming out from the street level to a typical satellite map style view. This view was useful for determining that the buildings were placed in the correct places in Canton. (To see directions on how to import files from Revit to Google Earth as we have done here, see Appendix A.)



Figure 43: Overview of Site

Conclusion

Our Major Qualifying Project began as just a structural design project, and it turned into a learning experience that allowed us to explore the capabilities of Building Information Modeling. The programs that we were able to use to design the buildings allowed us to not only get a better understanding of structural analysis, but also to learn software that the industry is just beginning to understand.

We set out to design buildings for three different locations in the center of Canton, ME as well as a bridge connecting a snowmobile trail to the center. We were able to do that, as well as publish all of the information to Google Earth so that when the idea is proposed to the town, it will be easy for people to visualize the potential idea.

We hope that these buildings will be created in the near future to bring more people into Canton and boost the economy of the town. They would also allow people to stay in the town instead of going elsewhere for a laundromat, restaurant, farmer's market, and potential apartments. Until they are built, we have created a Google Earth file that shows what they will look like on the actual topography of the area. Although they can be seen online, our hope is that in a few years, you will be able to drive through Canton and see them as well, and that our designs are not just Google Earth models, but buildings that are actually being used and enjoyed by those in the town.

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Appendix A

Transferring a Revit File into Google Earth

Importing Revit File into Google SketchUp

1. Export the created Revit file as a .dwg file
2. Open the .dwg file in AutoCAD 2010 or Civil3D 2010
3. Export the file as a .dwg 2004 CAD file
4. Import the 2004 CAD file into Google SketchUp**
5. You can now apply different textures and patterns to surfaces using Google SketchUp. All structural and architectural information will import, so beams and columns will still be within the structure and will be able to be seen in Google Earth.

Export from Google SketchUp to Google Earth

1. Open both Google Earth and Google SketchUp and locate the area that you would like to place the model.
2. Import the terrain from Google Earth into SketchUp by going to Tools→Google Earth→Get Current View.
3. Move the model around so that it is appropriately located in SketchUp.
4. Export the model from SketchUp into Google Earth by going to Tools→Google Earth→Place Model.
5. This file can be saved in Google Earth as a .kmz and opened later and it will bring you to the location of the models.

** If SketchUp does not have an option to import a .dwg file, visit this website <http://sketchup.google.com/support/bin/answer.py?hl=en&answer=161784> to download a plug-in. The newer version of Google SketchUp does not allow .dwg file imports, but downloading this will allow you to use these file extensions.