Final Thesis Report

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Construction Management

Anumba

The Duffy School

Florence, NJ

04/08/2015

THE DUFFY SCHOOL

210 West Second Street, Florence Township, NJ

The Duffy School
Courtesy of Conifer

BUILDING INFO

- Occupant Name – Conifer-LeChase
- Occupancy Type – Residential
- Size – 70,593 GSF
- Number of Stories – Three
- Dates of Construction – April 2014- April 2015
- Approximate Cost – $9.3 Million
- Delivery Method – Design-Bid- Build

PROJECT TEAM

- Owner – Conifer-LeChase
- General Contractor – Gary Gardner
- Architect – Kramer & Marks
- Civil Engineer – Stout & Caldwell
- MPE – McHugh Engineering
- Historic Consultant – Keystone Preservation
- Structural Engineer - SSM Group

ARCHITECTURE

- Renovation -35 apartment units
  - Fitness & Entertainment Room
  - Craft Room & Library
- Addition – 18 apartment units
- Façade – Brick Veneer, Curtain Wall
- Roofing – White EPDM
- Sustainability – NJ Housing and Mortgage Finance Agency Green Future Checklist

STRUCTURAL SYSTEM

- Substructure – Concrete
  - Slab-on-Grade
    - 4000 psi Normal Weight
  - Foundation Walls
    - 3000 psi Normal Weight
- Masonry – Striated and Splitfaced units
- Superstructure – Wood Frame
- Lateral System – Metal Straps
  - Hold Down Anchors

MECHANICAL SYSTEMS

- Location – Mechanical Room on Floor 1
- Roof Top Units – Six VAV Units
  - Natural Gas
- AHUs – Eight Units
  - Occupancy Controlled
- Fire Protection – Automatic Sprinkler System
  - Quick Response Heads

LIGHTING/ELECTRICAL SYSTEM

- Location – North side of Floor 1
- Main Switchboard – (1) 800A
- Panel Boards – (8) 120/208V
- Back Up Power – Diesel Generator
- Apartment Lighting – Fluorescent Fixtures
- Exterior Lighting – LED Sconces
- Shared Space Lighting – Pendant Fluorescent Fixtures

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Executive Summary

With every project there are many problematic areas that can be addressed and analyzed to help the project succeed. The Duffy School Addition and Renovation is like most projects and has several areas that need to be better analyzed. Throughout extensive research performed in the Fall Semester, I found four analyses that focus on problematic features of the Duffy School Addition and Renovation. They are based on areas of value engineering, critical industry issues, constructability review, and schedule and cost reduction. Analysis topics include the feasibly of installing rooftop solar panels, researching the requirements of performing construction on historical buildings, prefabricating the exterior walls on the addition, and implementing BIM on the project.

Analysis 1- Rooftop Solar Panels

This analysis focuses on improving the energy efficiency of the common/shared spaces in the Duffy School. The area of investigation would be to see if solar panels can be placed on the building to help pay for the energy consumed in the common areas. This analysis will investigate the different solar panels available, their ease of installation and maintenance, and the associated costs. The locations of the panels were first selected based on different criteria. The specific panel, inverter, mounting and racking were selected next. The overall cost of the solar panels were calculated and came out to $69,270.76 and the duration to install the panels was found at around 19 days. With the total cost and installation of the panels being low, adding solar panels to the building is recommended.

Analysis 2- Historical Requirements

This analysis focuses on improving the schedule by hiring an historical consultant for all the historical components of the school. The Duffy School Addition and Renovation needed to follow numerous historical guidelines according to the Duffy Urban Renewal Program and by Florence Township. These guidelines required many pieces of the existing school to be carefully removed and stored, so that they can be reused in the new apartment building. There were many other issues that a historical consulting firm would have been able to help with. Many discussions with an associate from the historical firm helped solve many of the historical problems that are causing schedule delays. With the amount of time saved, I do recommended hiring an historical firm.

Analysis 3- Prefabricated Exterior Wall Panels

This analysis focuses on schedule improvement by pre fabricating the exterior brick veneer. The Duffy School's new addition enclosure consists primarily of brick veneer façade and a small curtain wall. Covering large percentages of the building enclosure, the opportunity of using prefabricated panels or modular façade systems would potentially accelerate the schedule and reduce labor costs. By eliminating the use of traditional methods to enclose the building, the construction site would be less congested, offer higher quality and performance products, and help move quickly on the schedule. Different prefabricated wall systems were researched until the ideal one was selected. The total duration to install the panels was found to be right under

3 days and the total cost was found to be $72,840 more than traditional stick built. With the large cost added to the project, I do not recommend using prefabricated exterior panels.

Analysis 4- BIM Utilization

This analysis focuses on the use of BIM to improve the project. BIM was not used at all on this project but could have been used to improve the project in several ways. BIM could have been used from the start to turn the original school building drawings into electronic files. Having an electronic model of the building will have been able to show the problems with the as-built. Having an electronic model will also allow for the use of a clash detection software. Both reasons explained above should help to greatly reduce the total amount of RFI’s and ASI’s. BIM was found to be able to help the Duffy project in three different ways. BIM has many more uses, but for this project I recommend implementing BIM at a small scale.

Acknowledgements

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Alex Medvesky- Gary F. Gardner Inc.

Dominic DeSantis- Gary F. Gardner Inc.

Janine Owens- Conifer LLC.

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1.0 Project Background

The Marcella L. Duffy School was first opened in the 1870’s and served as the first public school in the community. The school was closed down in 2008 due to the expensive costs of the outdated heating, ventilation and air-condition systems. The Duffy School addition and renovation with turn the original school into an affordable senior citizen apartment complex. The original school building will be turned into 35 apartment units. The addition, which will be on the east side of the school, will add another 18 units. In addition to the 53 apartment units, there will also be a community room, fitness center, craft room, library, and an entertainment facility.

Table 1-General Building Info

Building Information	
Building Name	The Duffy School Addition and Renovation
Location	Florence Township, NJ
Function	Affordable Senior Citizen Housing
Size	70,593 GSF
Height	3 Stories (32'-4" Total Height)
Cost	$9.3 Million
Construction	April '14-April '15
Delivery	Design-Bid-Build

1.1 Client Information

[1]The owner of The Duffy School renovation and addition is a joint venture between Conifer Realty and LeChase Construction to form Conifer-LeChase Construction. Conifer Realty has over twenty years of experience in building affordable homes, while LeChase Construction is a full service construction management firm and general contractor. With over 75 years of combined experience, Conifer-LeChase Construction brings the depth of LeChase's construction experience together with Conifer's extensive knowledge of affordable housing, development and property management. Their history and experience in the affordable housing market as well as their technical knowledge, buying power and expertise allows Conifer-LeChase to provide their customers with the best in the industry. Together Conifer-LeChase Construction delivers high quality, value-driven housing projects with excellent service and support.

1.2 Project Delivery and Staffing Plan

The Duffy School renovation and addition is a design-bid-build project. The owner, Conifer-LeChase Construction, chose Gary Gardner Construction to be the general contractor. Gary Gardner Construction holds all the contracts with the subcontractors. Subcontractors were

[1] http://www.conifer-lechase.com/

selected based on a competitive bid process for some and negotiated sum for others. All contracts with subs are lump sums. No bonds were required from the subs, but general liability and workman' s compensation insurance were required.

The general contractor, Gary Gardner Construction, has representatives on site five days a week. John Abele is the project manager and is on site for the the regular meetings which occur every first and third Tuesday of the month. Dominic DiSantis is the supervisor on site and reports directly to Mr. Abele if needed. The superintendent, Mike Fisher, is on site full time and is incharge of daily tasks including quality control and quality assurance operations. Also on site is the field administrator, Alex Medvesky, who is in charge of taking pictures and documenting anything needed for historic concerns. Not on site is the project administrator who attends the monthly meetings as well.

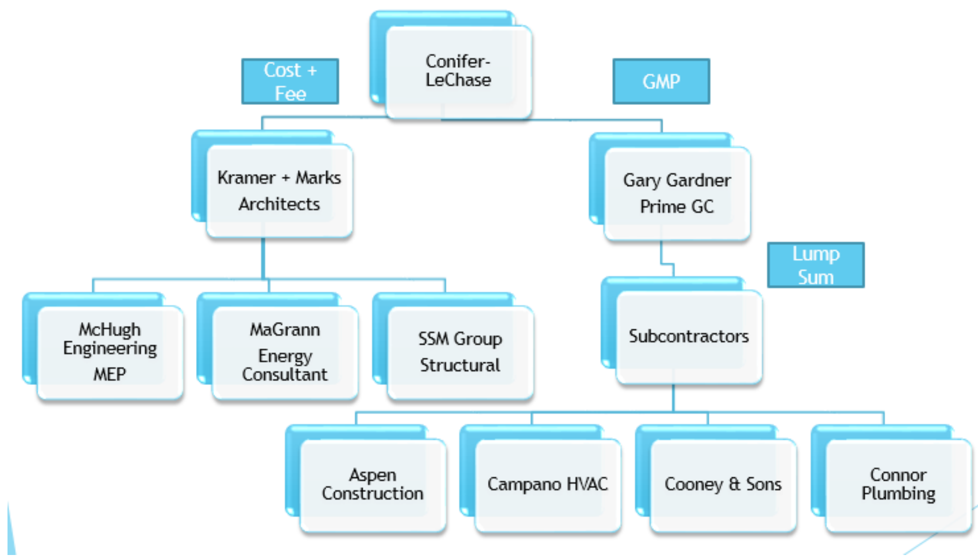


Figure 1-Project Delivery Method

1.3 Existing Site Conditions

On the site for The Duffy School addition and renovation sits the original Marcella L. Duffy School. To the east of the school there is a small parking lot and a small unoccupied house. To proceed with the addition to the school the parking lot and small unoccupied house had to be demolished. To the west of the school there is a blacktop that was used for outdoor sports, including basketball and four square. South of the school is W. Second Street which is a two lane, two way road and to the north is a small one way alley. On the other side of the alley are residences in which the work shall in no way impede the use and occupancy of those properties and must be coordinated with the property owners.

[2]

Figure 2- Aerial View of Duffy School

[2] Googlemaps.com

2.0 Design & Construction Overview

2.1 Building Systems Summary

Demolition

There was extensive demolition and removal of selected portions of the building and selected site elements. All existing mechanical systems were removed in their entirety including but not limted to the boiler system, piping, coils, valves, air handlers, etc. All the demolished materials were recycled wherever possible and any hazardous materials were disposed of in a safe manner. All existing plumbing systems were also removed in their entirety. The power and electrical systems remained active and had to be modified wherever needed. Due to the age of the school there were also numerous historical guidelines that needed to be followed according to the Duffy Urban Renewal Program and by Florence Township. All the black slate chalkboards and historical trim must be removed and carefully stored for reinstallation throughout the new building. All the historic tin ceilings and their patterns needed to be fully documented where they exist prior to any work. A piece of the cornice band, a piece of the border and a minimum of two square panels per room must be labeled and saved to be reproduced in the new building. The lobby columns and pediment vestibule also needed to be saved and protected during construction. This included completely covering the piece and not being able to work within a one foot radius of the historic piece.

Mechanical System

The Duffy School is cooled by six VAV packaged rooftop units and eight air handling units. The rooftop units are Mitsubishi MXZ8B48 4 ton, 48,000 BTU capacity with 208V/ 1 phase. The units provide conditioned air through the use of standard grille, register and diffuser terminals. Wall mounted thermostats with occupancy control need to be provided and must be fully programmable and interlocked with the roof top units.

The rooftop units also provide heating with the use of natural gas. Thirty six gas mains enter the building on the north west side of the building from gas meters on the exterior of the building.

The building will also be equipped throughout with an automatic sprinkler system with quick response sprinkler heads

Structural System

The structural system for the Duffy School Addition and Renovation is primarily wood framing. The basic vertical structure is constructed from 2 by 6 dimensioned lumber spaced 16” off center. These 2 by 6’s support the 18” deep, 4 by 2 wooden floor trusses spaced 19.2” off center for the first and second floor. The floor trusses are then covered with ¾” OSB sheathing that gets glued and nailed at 8” off center. The 2 by 6 second floor load bearing walls support the roof truss at 24” off center. The roof trusses get covered with a 5/8” plywood decking. The structural slab for the new addition is 4” thick concrete system over 10 mil vapor barrier on 4” crushed stone. The shear walls will have 2” x 18 metal fastened straps at each stud. The walls will also use Simpson Hold Down Anchors between each floor and between the bottom level and slab-on-grade. The building enclosure is wood stud with a brick veneer. For the existing building the brick façade was repaired/restored and the exisiting wall construction remained the same. The roofing system is a white EPDM roof system. The EPDM roof sits ontop of R-25 resnet grade 1 insulation. Under the R-25 insulation is a 2.5” layer of spray foam insulation and R-38 total roof insulation. The building will also have foundation walls constructed of 3000 psi normal weight concrete and the slab-on-grade uses 4000 psi normal weight concrete.

Electrical

The electrical utility service enters the building on the north side into the utililty transformer located in the vault. The service than travels to the main distribution panel at 800A, 208/120V, three phase, four wire. There are a total of 8 planelboards that supply the building with power. They range from the 800A main panelboard to the 100A panelboard used for the ground, first, second, and exterior lighting. There is also a 60KW outdoor diesel emergency generator incase of outages.

2.2 Engineering Support Systems

Lighting

The lighting plan for the Duffy School Addition and Renovation incorporates a combination of fluorescent fixtures and LED architectural sconces. The main lighting in the resident apartments is fluorescent fixtures, while shared spaces use 33” pendant fixtures. Exterior lights are LED architectural sconces placed by the entrances/exits. The main electrical room is located on the west side of the building on the ground floor.

Fire Protection

The existing automatic dry pipe system will be removed in its entirety from the Duffy School. The building will be equipped throughout with an automatic wet-pipe sprinkler system with quick response sprinkler heads. The wet-pipe system has 6” pipe for fire service and also 4” pipes which go to the newly added fire department siamese connection added on the north east side of the new addition.

Transportation

Given the building is designed for senior citizens, an elevator will be a crucial element to the mobility between the three floors of the building. One standard hydraulic passenger elevator will be installed in the connector area between the existing building and addition. A new set of egress stairs are also being added in the addition. The two sets of egress stairs will remain the same in the existing building.

2.3 Schedule Overview

The project schedule for The Duffy School Addition and Renovation was done using Microsoft Project and the actual full schedule can be found in Appendix A at the end of this report. This schedule breaks the building into the scope of work performed throughout the different phases of the project. The schedule has around two hundred and fifteen line items that range from the initial site clearing and grubbing, to the installation of the apartment appliances, all the way to the final inspection of each floor.

The Duffy School Addition and Renovation project schedule begins on April 21st, 2014 with a completion date of March 31st, 2015. The initial stage of securing the site and mobilization started in the middle of March of 2014 and takes place until mid-April. Demolition and abatement is then scheduled to take place on April 24th and last for over forty five days. The building addition and renovation then gets split into four different sections. The new addition of the eighteen apartment unit's starts on June 25th, 2014 and lasts until February 2nd, 2015. The new addition common space, which includes the corridor and stair tower, starts on October 21st, 2014 and is to be completed by February 2nd, 2015. The existing building apartment units are set to start on September 29th, 2014 and will be completed March 31st, 2015. The last section is the existing building common space, which includes the entertainment facility, craft room, library, fitness center, and community room. This part of the building is set to start on October 22nd, 2014 and be completed on March 31st, 2015.

A detailed schedule overview can be seen below, in Table 2.

Table 2-Project Schedule Overview

Project Schedule Overview			
Phase	**Start Date**	**Finish Date**	**Duration**
Mobilization	17-Mar-14	25-Apr-14	30
Demolition	24-Apr-14	24-Jun-14	43
New Addition	25-Jun-14	20-Feb-15	173
New Addition-Common Area	21-Oct-14	20-Feb-15	89
Existing Building	29-Sep-14	31-Mar-15	132
Existing Building-Common Area	22-Oct-14	31-Mar-15	115
Total Project Duration	**17-Mar-14**	**31-Mar-15**	**379**

The step after mobilization was to clear the site and to get rid of the structures that already existed on the land. These structures include a small house on the south east of the site and an addition to the school that was added in the early 1990's. These two structures will be completely demolished by the end of May. The next part of the demolition stage is the demolition and abatement of the existing school building. This is the longest task in this phase and takes right around forty days.

The existing building apartments' stage starts with the framing of each unit. There are a total of thirty five units. These units take twenty four days to complete and again follow the same order as the new building, with the framing starting on the second floor and working down to the ground floor. The next steps are the same as the new building with MEP rough in and the installation of drywall, doors, etc. A main difference now occurs with the placement of the historical windows, trim, and tin ceilings. These pieces were saved or restored from the original building during the demolition stage. Replacing these historical details takes around forty days due to the carefulness and precision that is required. Once the historical pieces are replaced the appliances and finishes can be installed in the apartment units.

The common spaces in the existing building are a lot bigger than the common space in the addition. In addition to the corridors and stairwells there is also an entertainment facility, craft room, library, fitness center, and community room. The steps for this phase are the same as the existing building, due to the fact that there are some historical features that need to be installed in the common spaces as well. The historical trim and tin ceiling tile take less time to install in the common space than in the apartments. A difference from the rest of the structure is the installation of the trash cute which takes five days. Once the existing building common space is completed in the end of March 2015, the entire project can be inspected and be 100% completed on March 31st, 2015.

2.4 Cost Overview

The actual cost of construction for the 70,600 GSF addition and renovation for The Duffy School in Florence, New Jersey was $5,522,588 or $77.77/SF. This cost takes into account the cost of material, labor, and equipment that is needed to construct the building. When including additional costs like furnishings and equipment, the total project costs rises to $9,290,265 or $130.83/SF. A cost breakdown of the different building systems, including the actual costs, cost per square foot and the percentage of the total cost can be seen below in Table 3.

Table 3-Cost Summary

Cost Summary			
Building System	**Actual Cost**	**Cost/SF**	**% Cost**
Site Work	$540,381	$7.61	9.78%
Demolition	$250,596	$3.53	4.54%
Concrete	$227,258	$3.20	4.12%
Masonry	$318,935	$4.49	5.78%
Carpentry	$869,431	$12.24	15.74%
Doors, Frames, & Hardware	$214,508	$3.02	3.88%
Windows	$663,063	$9.34	12.01%
Flooring	$260,019	$3.66	4.71%
Plumbing	$578,135	$8.14	10.47%
HVAC	$727,944	$10.25	13.18%
Electrical	$872,318	$12.28	15.80%
Total Construction Cost	**$5,522,588**	**$77.77**	**100%**
Overall Project Cost	**$9,290,265**	**$130.83**	**168.22%**

2.5 General Conditions Estimate

The general conditions estimate performed for the Duffy School Addition and Renovation represents the operational costs of the jobsite for the general contractor Gary F. Gardner Construction. The estimate was broken down into six different sections which includes supervision/project management, field engineering, administrative, safety, cleanup, and miscellaneous.

Table 4-General Conditions

General Conditions Summary		
Section	**Cost per Month**	**Total Cost**
Project Management	$22,758	$273,104
Field Engineering	$1,471	$17,658
Administrative	$5,953	$71,435
Safety	$56	$670
Cleanup	$4,838	$58,059
Miscellaneous	$362	$4,339
Total	**$35,440**	**$425,265**

The table above shows the general conditions estimate summary for the six main sections as noted above. The total cost of the project general conditions is $425,265.00 which is 4.6% of the negotiated lump sum contract value for the project at $9,290,265. With the general conditions estimate taking place over a 12 month period I divided the total by each month and found that general conditions cost around $35,440 a month. The prices were found by using a combination of 2013 RS Means Construction Cost Data and actual known costs from previous projects. The most expensive out of the six sections was for project management. This section was 6% of the total cost, followed by administrative at 17%, cleanup at 14%, field engineering 4%, miscellaneous 1% and finally safety at less than 1%.

2.6 LEED Evaluation

In New Jersey in order to receive Federal Low Income Housing Tax Credit (LIHTC), the building owner has to decide which form of "Green Points" they wish to acquire for the project. There are three main ways to gain the required Green Points: Solar Hot Water or Water Retainage and Reuse System, Green Future Program, or LEED Certification. For the Duffy School Addition and Renovation, the owner decided not to go with LEED Certification but instead to use the Green Future Program.

The Green Future Program consists of a list of basic green building items that cover energy efficiency, renewable resources, siting & land use, water conservation, building durability, indoor air quality, and operations and maintenance. Beyond energy savings and generation, the Green Future Program works to create pleasant and healthy interiors for the residents. The full Green Future Program Checklist can be found in Appendix F. For these points to be acquired all items on the checklist must be completed. To complete some of the items, photographic evidence must be presented in the final report as well as a copy of the drawing or the drawing number and exact location of the item.

Some of the categories that needed to be completed for the Green Future Program are:

Site and Planning

This category includes the preservation plan, historical preservation plan, and pedestrian paths and bike trials. The preservation plan requirement is to minimize disturbed areas and preserve viable existing trees and vegetation. The benefit of this requirement is existing trees can provide shade, reduce cooling loads and provide comfortable outdoor spaces in summer. The historical preservation plan requirement is to submit documentation indicating the historic status of the building. The benefit of this requirement is because preserving the existing structure and historic character of a building has inherent 'green' qualities. This Green Future option seeks to not waste the energy in pre-existing and constructed materials.

Indoor Air Quality

This category includes automatic bathroom ventilation and direct vent of kitchen. The automatic bathroom ventilation requirement is to install fans that directly vent to the outside in bathrooms with automatic timer control. This is to eliminate the fan noise to help ensure ventilation utilization because nobody will turn it off since it is not too noisy. The automatic controls will increase ventilation and minimize potential odors, moisture, and smoke. The direct vent of kitchen requirement is all kitchen exhausts shall be directly vented to the outside. The benefits of this is because not all people use operable windows in the kitchen to ventilate smells, due to varying exterior temperatures and the use of HVAC. This direct vent will get rid of odors so there will be no residual smells in the units.

Energy Efficiency

This category includes energy star appliances. The energy star appliance requires that refrigerators, clothes washers, and dishwashers must be ENERGY STAR rated and all washing machines must be front loading. The benefit of energy start appliances are they require only about half as much energy as non-energy rated appliances. The energy rated dishwasher and clothes washing machines also save water and energy.

LEED

The owner did not decide to go with LEED Certification for this project. However, by comparing the Green Future Checklist with LEED v4 for New Construction and Major Renovation, the LEED certification that this project could have received was calculated. The Duffy School could have potentially earned 58 points which would make the project

LEED Silver. The Green Future Checklist and LEED program are very similar with the main difference being points are awarded in the LEED program while every item must be fully completed in the Green Future Program.

3.0 Rooftop Solar Panels

3.1 Problem Identification

The Duffy School Addition and Renovation is going to turn and old elementary school into affordable apartments for senior citizens. Of the 52 new apartment units, 7 are held for households that make at or below 30% of the area medium income, 20 for households at or below 50% the AMI, 21 for households at or below 60% the AMI, and the remaining 5 will be for homeless seniors. The homeless seniors will have some of their food and clothes taken care of by the local Catholic Diocese of Trenton. As well as the 52 apartments, the new building will also come with amenities. These amenities include a community room, fitness center, library, craft room, and entertainment room. The one problem with all these extra rooms is figuring out how the energy used in those areas will be paid for.

The addition to the Duffy School has available roof space, which would allow for the implementation of solar photovoltaic panels. These panels would help cover the cost of the mechanical and electrical systems in the common areas.

3.2 Proposed Solutions

The Duffy School Addition and Renovation has the opportunity to add solar panels to the rooftop to help with the energy consumption in the common spaces. An analysis needs to be performed to determine whether the solar panels will improve the future costs associated in the building. This analysis will explore how many solar panels are needed, how the procurement and installation process would affect the overall schedule, and the added costs and payback period for the new equipment.

After completing the analysis there are several potential solutions that could occur.

- The upfront cost of solar panels is too high and therefore will not be used.
- The amount of solar panels needed to power the common spaces is too large and there is not enough space for the panels.
- There is enough sunlight and the savings outweigh the upfront costs. If this is the case the solar panels will be used.
- The historical aesthetic of the building is compromised and therefore the solar panels should not be used.

3.3 Background Research

After some research, the main area of concern for the energy used in the shared spaces in The Duffy School Addition and Renovation is the incorporation of a photovoltaic system. The photovoltaic system is a good option for buildings that have the proper sunlight needed and have enough space for panels. The cost of the panels can be compared to long term savings. The amount of panels, men needed, and time of installation can also be researched.

There are two different types of solar panels that could be used for The Duffy School Addition and Renovation. The first type is a monocrystalline silicon or single silicon panel. This type of panel is the most efficient, having an efficiency that is typically within the range of 135-170 watts per m^2. The cells are all aligned in one direction, which allows them to be extremely efficient once they are placed at the correct angle when the sun is shining brightly. These panels typically have solar cells that are black in color and the corner cells are usually missing due to the production process. This type of panel works well in cooler conditions and are currently the most commonly used cells in the market. These solar cells also have an excellent life span and longevity and most come with 25 year warranties.

The other type of solar panel that was researched is a polycrystalline silicon or multi-silicon. This type of panel has an efficiency that is typically within the range of 120-150 watts per m^2. The individual cells are not all perfectly aligned together which allows for some losses at the joints between them, which makes them less efficient than the single silicon ones described above. These panels are typically light or dark blue in color. These panels perform better in hotter conditions and are generally less expensive to produce. These solar cells also have an excellent life span and longevity and most come with 25 year warranties as well.

For The Duffy School Addition and Renovation, single silicon solar panels will be researched fully to be implemented.

3.4 Analysis Procedure

The following procedure should be completed to successfully analyze the lifetime building energy costs associated with the common spaces in The Duffy School Addition and Renovation.

- Research different types of photovoltaic systems.
- Calculate amount of energy used in the common spaces.
- Look into sunlight properties of the site.
- Calculate cost and schedule changes associated with procurement and installation.

3.5 Predicted Outcome

After seeing how much energy gets used in the common spaces, the goal is to encourage the owner to put the money towards the cost of the photovoltaic system. The photovoltaic system will help save the residents and owner money from not having to pay for the energy in those shared spaces. The installation of the panels should not add time to the schedule because it can be done concurrently while interior work is being completed. The solar panels will also add enough value to the project that even with the panels, the aesthetic of the building will not be changed.

3.6 Solar Panel Design & Installation Process

Location & Sunlight

The first step in designing the solar PV system is figuring out where the panels can be located to receive an adequate amount of sunlight. Shading calculations were completed for the panels to determine the distance from adjacent roof tops mechanical equipment that could potentially obstruct the incoming sunlight. Using the solar shading chart for Florence, New Jersey provided by the University of Oregon SRML in Figure 3, the minimum distance from those obstructions was calculated. For the solar panels in Florence Township, six hours of exposure in the winter is recommended.

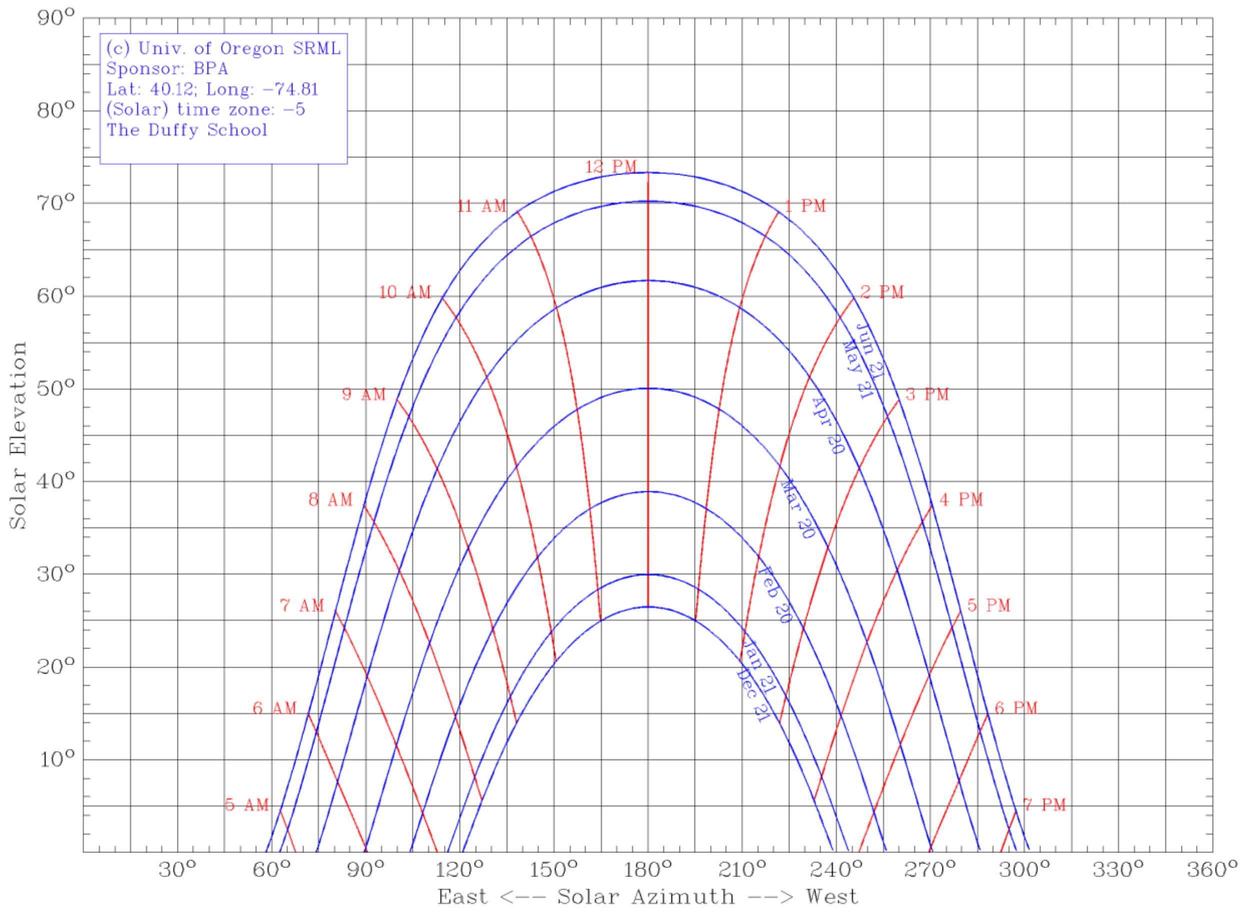
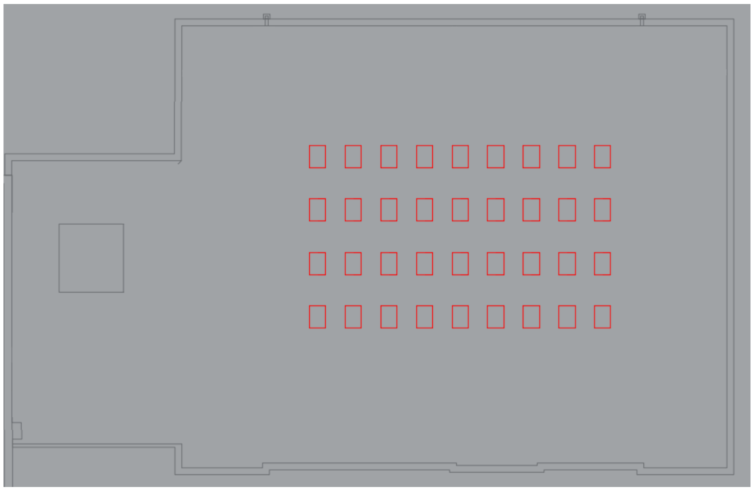


Figure 3-Solar Shading

For the Duffy School, there are no obstructions around that would affect the sunlight from hitting the solar panels. The location of the solar panels can be seen below in Figure 4.

[3]



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[3] Created in AutoCAD

Figure 4-Panel Locations

Panel Size & Number

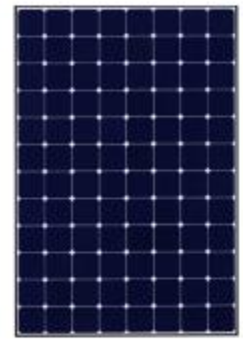

Figure 5-X21 Panel

[4]Once the location was determined for the solar panels, the specific panel was then chosen. For the Duffy School Addition and Renovation, it was recommended that the SunPower X21-345 Panel would be appropriate. These panels are ideal for residential buildings and can produce 44% more power per panel than other panels and can produce 75% more energy per square foot over 25 years. These panels are built on a solid copper foundation that will keep it from cracking and corroding due to the harsh conditions they could experience.

The next step is to determine the number of SunPower X-21 modules that will be needed to adequately power the common areas of the building. All the receptacles, equipment, and utilities that needed to be powered by the solar panels were calculated and can be found in the **Electrical Breadth**. With the total kWh per month found I used an online calculator to figure out how many panels were needed. With 6 hours of sunlight daily it was estimated that 36 panels will be needed. These panels will be placed on the roof in 4 rows of 9 panels.

Inverter Selection

Once the specific solar panels were selected and the amount of panels was calculated, an inverter was selected. For the Duffy School Addition and Renovation the UltraLITE Model ELU14000 Centralized Inverter was chosen because the output of the circuit voltage and current for the solar panels was within the range of the inverter specifications. The rating of 14,000 watts should be more than adequate for the estimated designed 12.42 KW output of the solar panels.

The inverter will be installed on the same roof as the solar panels to the east side of the panel array as seen in Figure 6. This is close enough to the solar panel array to keep the roof from becoming too congested and close enough to keep the cord run from the panels to the inverter minimal incase the panels need to be disconnected quickly.

[4] http://us.sunpower.com/sites/sunpower/files/media-library/data-sheets/ds-x21-series-335-345-residential-solar-panels-datasheet.pdf

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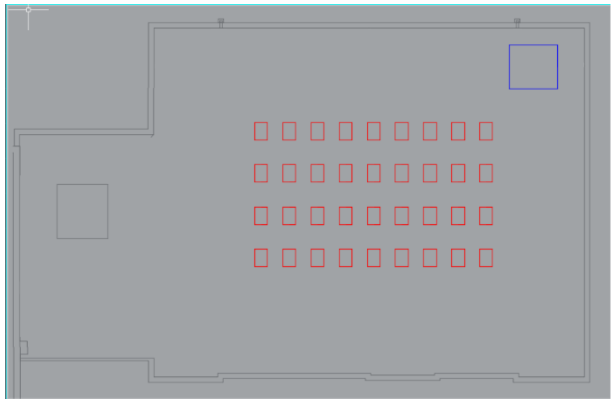


Figure 6-Inverter Location

Mount & Racking

[6]The solar panels for the Duffy School will be applied directly to the roof, so the Iron Ridge XR1000 roof mount was selected. This type of mount can be placed on all types of roof and works well on EPDM, which is the roof type the building will have. To install these mounts, the base is first drilled into the roof and all the holes are fully sealed. After the base is installed, the rails all get spliced together and placed and fastened on the base at the specified height. The clamps are then placed on the rails to allow the solar panels to attach to the mount. These steps are repeated over and over until all mounts have been installed for the 4 different rows of the solar array.

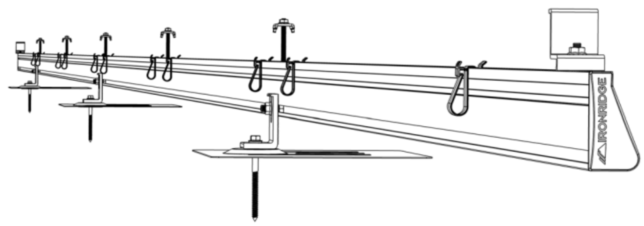


Figure 7-Mount and Rack

3.7 Feasibility Analysis

A feasibility analysis will be helpful in detailing the cost and schedule to decide whether the proposed photovoltaic system is a good option for the Duffy School Addition and Renovation.

Schedule Analysis

The installation process for solar panels has 7 main steps. The first step is to install mounts on the roof. From RS Means, one mount takes an estimated 1.25 hours to completely install. The next step is to connect the racks to the previously installed mounts. Again by using RS Means it is estimated that a row of 9 panel racks can be connected to the mounts in .75 hours. The third step in the solar panel installation process is to attach the SunPower Panels to the racks. It is estimated that each solar

[5] Created in AutoCAD
[6] http://www.ironridge.com/products/roofmounting/360view

panel can be attached in 1 hour. The inverter is the next to be installed on the roof and again from RS Means is estimated to take 4 hours to be completed.

Next a circuit break must be installed on the building and that takes an electrician around 1.5 hours to connect. The next step is for that electrician to run the wires. For the SunPower solar panels #12 and #8 AWG wires need to be ran. A total of only 20 linear feet of wire need to be ran for the #12 and 6 linear feet need to be ran of the #8. Each wire takes around .5 hours to run a linear foot. The last step is to run the conduit for the wires. A total of 1153 linear feet of ¾” conduit needs to be ran and a total of 42 linear feet of ½” conduit needs to be ran. From RS Means it is estimated to .25 hours to run a linear foot of the ½”conduit and only around 2 minutes for the ¾”. The total hours is 147.6 or around 19 days to completely install the solar panels and can be seen below in Table 5.

Table 5-Panel Duration

Solar Panel Installation				
Item	Qty.	Unit	Hours	Total
Mount	36	Ea.	1.25	45
Rack	4	Per 9 Mounts	0.75	3
Solar Panels	36	Ea.	1	36
Inverter	1	Ea.	4	4
Circuit Breaker	1	Ea.	1.5	1.5
#12 AWG	20	LF	0.5	10
#8 AWG	6	LF	0.5	3
3/4" Conduit	1153	LF	0.03	34.6
1/2" Conduit	42	LF	0.25	10.5
				147.6

[7]

Task Name	Duration	Start	Finish
Install Roof Mounts	6 days	Mon 1/12/15	Mon 1/19/15
Install Racking	1 day	Tue 1/20/15	Tue 1/20/15
Install Panels	5 days	Wed 1/21/15	Tue 1/27/15
Install Inverter	0.5 days	Wed 1/28/15	Wed 1/28/15
Install Circuit Breaker	0.5 days	Wed 1/28/15	Wed 1/28/15
Run Conduit	6 days	Thu 1/29/15	Thu 2/5/15
Pull Wire	2 days	Fri 2/6/15	Mon 2/9/15
System Check	1 day	Tue 2/10/15	Tue 2/10/15

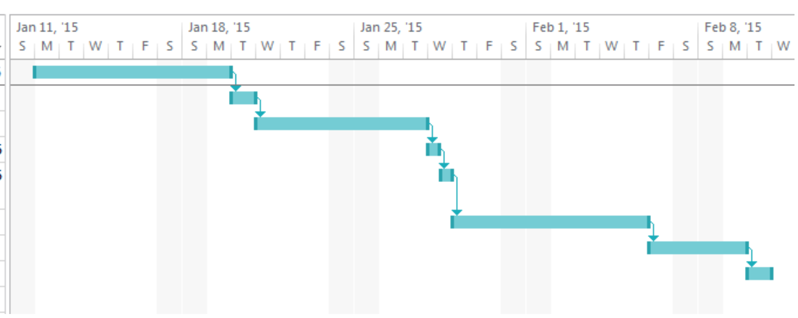


Figure 8- Solar Panel Schedule

[7] Created in MS Project

Cost Analysis

The costs for the solar panels can be seen below. For the standard items, like the conduit and wires, RS Means was used to calculate the total cost. For the solar panels, an estimate was given by Martin Doran from SunPower's East Coast office in Hamilton, New Jersey. He told me each panel costs around $426.25 and the installation is estimated to cost $3.18 per watt. The mount and racking price was found online by a local retailer. The total cost to install the solar panels is $69,270.76. This cost includes all the equipment, parts, and labor necessary to fully install the 36 solar panels which are needed to power the common areas of the Duffy School Addition and Renovation

Table 6-Solar Panel Cost

Solar Panel Cost				
Item	Cost	Qty.	Unit	Total Cost
Mount	$0.11	12420	Watt	$1,366.20
Rack	$322.54	4	Ea.	$1,290.16
Solar Panels	$426.25	36	Ea.	$15,345.00
Inverter	$5,153.88	1	Ea.	$5,153.88
Circuit Breaker	$912.05	1	Ea.	$912.05
#12 AWG	$47.69	20	LF	$953.80
#8 AWG	$89.23	6	LF	$535.38
3/4" Conduit	$3.57	1153	LF	$4,116.21
1/2" Conduit	$2.44	42	LF	$102.48
Solar Panel Installation	$3.18	12420	Watt	$39,495.60
				$69,270.76

3.8 Conclusion & Recommendation

The Duffy School Addition and Renovation has the opportunity to help cover the costs of the common areas for the low income senior citizens. These common areas are a great feature to have in the apartment complex, but the only issue with it is figuring out how the bills will be paid. With the initial upfront cost of the panels being relatively low, it is my recommendation to add the solar panels on the addition rooftop. These panels will pay for themselves in only 11 years and after that they will be generating money which can be used to help the senior citizens in other many other aspects.

Overall, installing the solar panels will benefit the residents right away and after the estimated payback period will benefit the owner as well. The solar panels should be installed and used on this building.

4.0 Electrical Breadth

About

This analysis explores the amount of energy used in the previously mentioned common areas for the photovoltaic array and will determine the expected payback period. This analysis will look into how much energy will be consumed in the common space and will help with **Analysis I** in determining the amount of panels needed to distribute the electricity safely and efficiently.

Electrical Usage

For this analysis, all the equipment that is to be power by the solar panels was found (receptacles, lighting, dryer, washer, fridge, etc.). With the equipment and the amount of each that will be in the building found, the wattage of each piece was next found in the electrical documents provided by Gary Gardner Construction. The equipment usage each day was estimated in hours. This estimate was found by thinking about how long each piece of equipment will be running each day with all 56 apartments filled.

Once the wattage and daily usage was found, the estimated kilowatt hour per day was found by multiplying the two. This was then turned into the amount of kilowatts used per month and then again converted to kilowatts used per year. The cost per kilowatt was found by contacting the local energy provider, North American Power. This was found to be around 11 cents per kilowatt hour. With all the above information the cost per kilowatt hour per year was found for each piece of equipment and the total price was found by adding them all together. The estimated electrical cost of the different pieces of equipment in the common area was found to be a little under $20,000.

Table 7- Electrical Usage

	Power Usage					
Equipment	Amount	Watts	HRs	kWh/Day	kWh/Month	kWh/Year
TV Room RCPT	2	360	8	5.76	172.8	2073.6
Gym TV RCPT	1	360	6	2.16	64.8	777.6
Comm Room RCPT	6	1260	8	60.48	1814.4	21772.8
Comm RM Fl RCPT	2	720	8	11.52	345.6	4147.2
Computer RM RCPT	7	180	4	5.04	151.2	1814.4
Comm RM Kitchen RCPT	2	180	4	1.44	43.2	518.4
Craft RM RCPT	2	1260	4	10.08	302.4	3628.8
Doctors RCPT	1	900	8	7.2	216	2592
Fitness RCPT	1	1080	4	4.32	129.6	1555.2
Comm RM LTG	2	1500	12	36	1080	12960
Dryer	4	5600	8	179.2	5376	64512
Dishwasher	1	1200	2	2.4	72	864
Washer	4	1200	8	38.4	1152	13824
Fridge	1	900	24	21.6	648	7776
Fireplace	1	500	4	2	60	720
Trash Compactor	1	2500	8	20	600	7200
Treadmill	6	1200	8	57.6	1728	20736
Total	**44**	**20900**	**128**	**465.2**	**13956**	**167472**

Payback Period Analysis

In figuring out how much electricity the solar panels will generate, an online solar calculator was used. This calculator takes into account to total price of the PV system, the United State Federal Tax incentives, the New Jersey Tax incentives, and the New Jersey residential Energy credit. With all these costs and incentives figured out, the total cost of the PV system was found.

Next the total output of the PV system was found by taking the total amount of panels, multiplying it by the output of each panel and calculating in the amount of direct sunlight each day. With that the estimated monthly saving of the solar panels was found. Each month the solar panels were found to save $3,559. With that know cost, the payback period was found. For the SunPower X-21 on the Duffy School Addition and Renovation it was found to take 11 years to payback the system. After the 11 year mark, the panels will start bringing in money.

The payback analysis can be seen below in Figure 9.

Payback Analysis
for SunPower x-21 Series
a Grid-Tied PV System in New Jersey
with State Solar Incentives

INITIAL COSTS AND BENEFITS	Quantity	Unit Cost	Total	Salvage Value	
INITIAL SYSTEM COST				% Factor	Amount
Solar Panels	36	$ 426	$ 15,345	25%	$3,836
Mounts	12420	$ 0	$ 1,366	0%	$0
Rack	4	$ 323	$ 1,290	0%	$0
Inverter	1	$ 5,154	$ 5,154	0%	$0
Circuit Breaker	1	$ 912	$ 912	0%	$0
#12 AWG	20	$ 48	$ 954	0%	$0
#8 AWG	6	$ 89	$ 535	0%	$0
3/4" Conduit	1153	$ 4	$ 4,116		
1/2" Conduit	42	$ 2	$ 102		
Labor	12420	$ 3	$ 39,496		**$3,836**
Initial System Cost Total			**$69,271**		
U.S. Federal Tax			2,000		
New Jersey Tax	$2.50	$ 3,960	$9,900		
System Cost after Basic Credits			**$57,371**		
New Jersey Residential Energy Efficient Credit			$5,000		
Total			**$52,371**		

ANNUAL PRODUCTION	
Number of Panels	36
STC Rating in Watts Per Panel	350
Total watts per hour assuming optimum conditions	12,600
Performance under real world solar conditions	80%
Adjusted watts per hour assuming real conditions	10,080
Average hours of sunlight per day	6.0
Estimated kilowatt hours per day output	60,480
Estimated kilowatt hours per year	22,075
Florence , NJ electric rate	$0.12
Estimated Income (Year 1)	$3,559
Electrical Rate Annual Inflation Assumption	4.0%
Combined State and Federal Income Tax Bracket	30%

REVENUES AND EXPENSES	2008 Year 0	2009 Year 1	2010 Year 2	2011 Year 3	2012 Year 4	2013 Year 5	2014 Year 6	2015 Year 7	2016 Year 8	2017 Year 9	2018 Year 10	2019 Year 11	2020 Year 12
Initial System Cost & Salvage Value	**-$52,371**												
Electricity Sales		$3,559	$3,701	$3,849	$4,003	$4,164	$4,330	$4,503	$4,683	$4,871	$5,066	$5,268	$5,479
Cumulative Electricity Sales		$3,559	$7,260	$11,110	$15,113	$19,277	$23,607	$28,110	$32,793	$37,664	$42,730	$47,998	$53,477
Simple Payback (Personal) {Year cash flow turns positive}:		**-$48,812**	**-$45,110**	**-$41,261**	**-$37,258**	**-$33,094**	**-$28,764**	**-$24,261**	**-$19,577**	**-$14,707**	**-$9,641**	**-$4,373**	**$1,106**

Figure 9-Payback Period

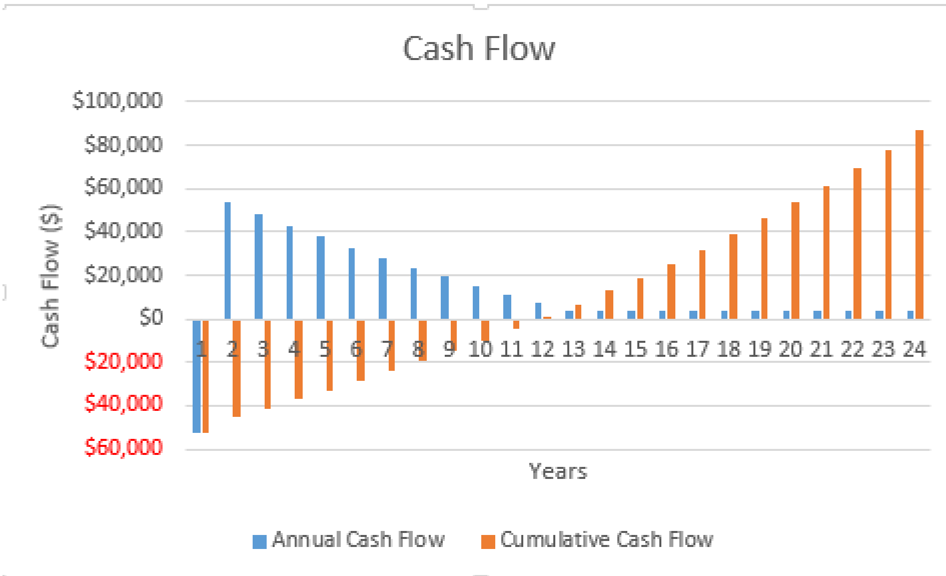


Figure 10- Cash Flow

Conclusion

After analyzing the estimated income of the panels and comparing it to the direct and indirect costs of installing and operating the solar panel system, it was concluded from a performance and electrical perspective that the solar panels are a worthwhile feature to add to the Duffy School Addition and Renovation.

5.0 Historical Requirements

5.1 Problem Identification

Due to the age of the school there were numerous historical guidelines that needed to be followed according to the Duffy Urban Renewal Program and by Florence Township. All the black slate chalkboards and historical trim must be removed and carefully stored for reinstallation throughout the new building. All the historic tin ceilings and their patterns needed to be fully documented where they exist prior to any work. A piece of the cornice band, a piece of the border and a minimum of two square panels per room must also be labeled and saved to be reproduced in the new building. All the historical pieces were labeled and placed in the old gymnasium, on the stage and on the floor. These pieces were all individually labeled and placed in the storage pile. Once the gymnasium renovation started to turn in into an entertainment center and fitness room, all the historical pieces must be moved to a completed apartment for storage until it is needed in the building.

Along with the problems of labeling and placing the historical pieces that must be saved, there were also big issues with acquiring the right types of windows to match the existing building. The installation of the preserved pieces that need to be put back into the new and existing building are also causing problems and schedule delays.

5.2 Proposed Solutions

The Duffy School Addition and Renovation has the opportunity to shorten the overall project schedule by hiring an historical firm to deal with the historical requirements of the building. An analysis needs to be performed to see if the cost added by hiring a historical firm will offset with the accelerated schedule.

After completing the analysis there are several potential solutions that could occur.

- The upfront cost of the firm is too high and therefore will not be used.
- The site does not have enough space for some of the proposed solutions and therefore will not be utilized.
- The amount of time saved is substantial and therefore will be used.

5.3 Background Research

After some research there are two areas of concern for how the historical pieces were preserved and stored. The first area of concern is the number of men needed to individually label and store each piece. During the demolition and abatement stage many extra men were needed to take down the historical pieces, label them all, and then place them in the gym for storage. Extra men were needed again when the historical pieces had to be transferred to a different room.

The next area of concern is the time needed to move the pieces around. The schedule is fast paced and the time needed to get the pieces out of the gym into another room will greatly slow the progress.

The amount of men needed, the time saved, and the cost of a container can be compared to see if having an onsite container to store the material is a better option than storing the material inside the building

The next area of concern deals with acquiring the new windows for the new and existing building that need to match the windows that currently exist on the old school building. This was not originally thought to be an issue so once the windows were ordered, the time for delivery was much longer than estimated and is pushing many tasks back. If an historical firm was hired for this project they would have been able to know the issues with deliveries and would have had the windows ordered much earlier on in the project.

The last area of concern is with the long times given for the tasks of reinstalling the historical pieces. This was given extra time because many of the pieces needed to be repaired before being reinstalled, due to the improper ways they were taken down, transported, and stored.

5.4 Analysis Procedure

The following procedure was completed to successfully analyze the use of an historical firm for The Duffy School Addition and Renovation.

- Research historical consulting firms in the area.
- Calculate men needed for material movement.
- Calculate time needed to move pieces.
- Check site for adequate space.
- Calculate any added costs of firm and/or extra equipment needed.

5.5 Predicted Outcome

Hiring an historical consultant for the project should help in several ways. Using onsite storage instead of storing the materials inside should save enough time on the schedule to offset the cost of the container rental. By having a container on site, the materials will only have to be placed in the container in the early stages of construction and will not have to be touched or moved until they are ready to be replaced in the building. Also the consulting firm will know about ordering historical windows so the delay in delivery should be resolved. Lastly the firm will know how to takes down and better preserve the pieces to make installation quicker and easier.

5.6 Historical Consulting Firm

The Marcella L. Duffy School was originally opened in Florence New Jersey in the 1870's. It originally started as a four-classroom building and was the first public school in the community. In the 1950's the school was expanded to a K-8 school and stayed that way until the school building was closed down for good in 2007. The school building was purchased from the town and the new owners decided to turn the building into affordable apartments for senior citizens, while still preserving the historic integrity of the structure.

With a unique project like the Duffy School, many historical requirements needed to be followed. One of the requirements was that all the existing trim, details, flooring, ceilings, and windows needed to be saved and preserved in the old gym/auditorium on the first and second floor. Another requirement was the original front door needed to be removed and securely stored for reinstallation in the same location after it was thoroughly cleaned and the frame was fixed. Another requirement is the columns and pediment vestibule needed to be saved and stored properly. Another large requirement was to remove and carefully store all the black slate chalkboards and the historical trim for reinstallation throughout the new rehabilitated building. The last large requirement was to document the ceiling painting in the specific rooms and to replicate in the new apartments. The ceiling patterns can be seen below in Figure 11. Figure 11 shows the three different ceiling patterns being used and also shows the different locations for [8]the blackboards, trim, and baseboards.

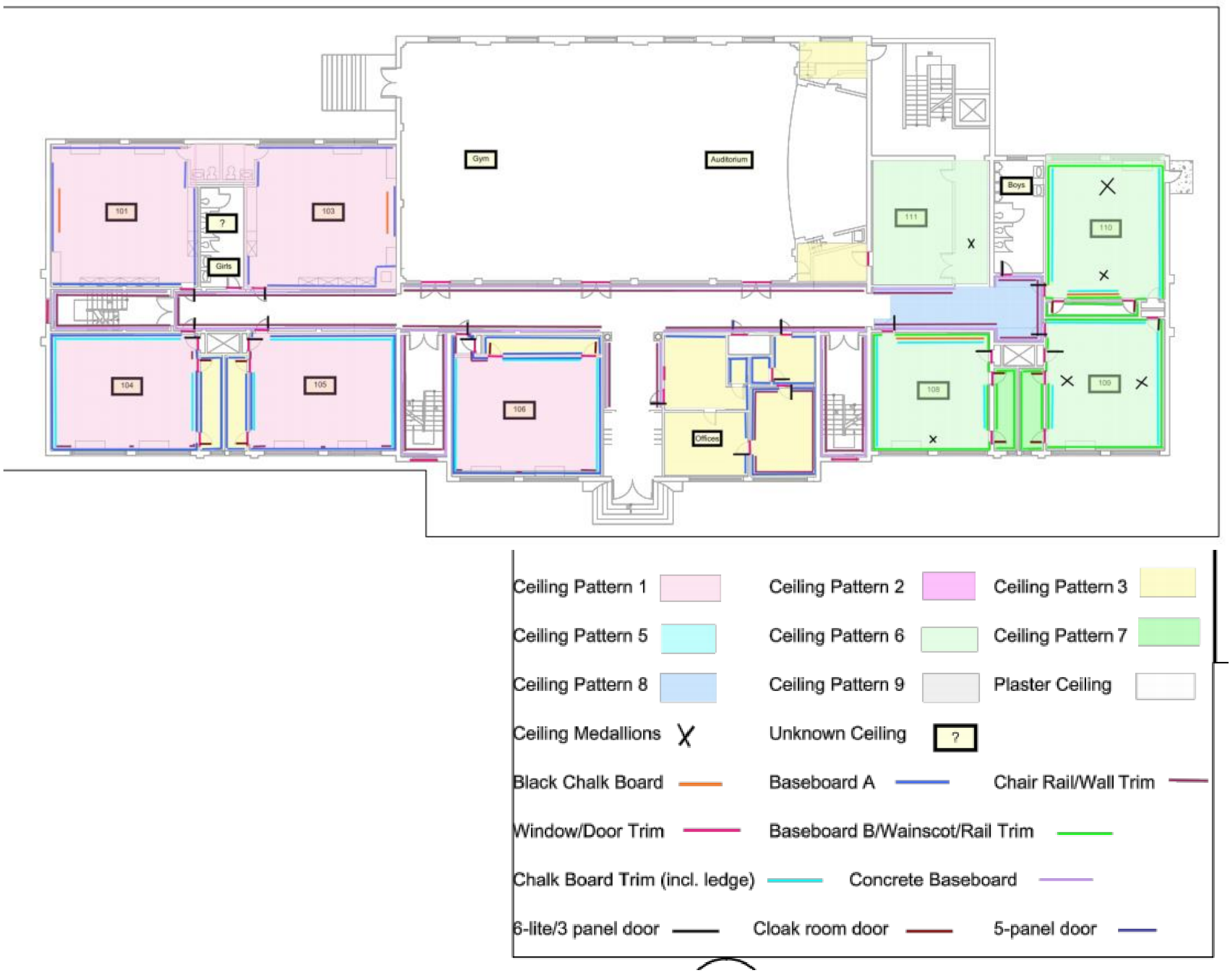


Figure 11-Historical Requirements

To help with all the planning and coordination of the historical requirements for The Duffy School Addition and Renovation, an historical consulting firm could be beneficial. Historical consulting firms can do many things including analyzing historic architectural finishes, mortar analysis, preconstruction testing and item removal and repair, can help with item procurement,

[8] Construction Documents provided by Gary Gardner Construction

and can do conditions documentation. Conditions documentation includes making reports which identify possible problematic issues and can discuss potential options for treatment.

For the Duffy School in Florence, New Jersey, a local historical consultant could be the Keystone Preservation Group. They are located in Doylestown, Pennsylvania which is less than 45 minutes from the site. The Keystone Preservation Group has worked on many buildings in Washington DC, Pennsylvania, New Jersey, Maryland, and even has worked on several buildings on the West Coast. After giving the Keystone Group a call, I explained the large issues with the project and the associate conservator, Elizabeth Lizzy, discussed the ways in which the Keystone Group would be able to help. Three of the main ways can be read about below.

On Site Containers

[9]I first discussed the schedule delays associated with the storage of the historical items to Mrs. Lizzy. One of the issues being that the items are all originally stored in the old gymnasium on the stage and the floor surrounding, as seen in Figure 12 on the right. Once the gymnasium starts to get worked on, the items are moved from that area and placed in one of the apartments that is close to be completed, which for this project is room 101 or a room to the west side of the school building. This room is not that far from the gym, but the walk from the stage to room 101 takes around 3 minutes. There are a lot of historical pieces in storage, so the moving from one room to another takes valuable time.

Figure 12-Current Material Storage

Mrs. Lizzy suggested the project should invest in an on-site container to hold the historical pieces from the start of the project until the pieces are reinstalled in the building. The on-site container will take away the need to place and then move the items. Instead the pieces can be taken down and put instantly into the container. Once in the container, the piece can remain untouched until it is needed, towards the end of the project schedule.

The on-site container seemed like a great solution to the historical piece storage issue. The only things I needed to check on was the added cost of the container and if there is enough space on the construction site. After researching different types of storage containers, the Tyson Onsite 20' container would work perfectly. This container was quoted to cost around $475 per month. It would be needed for the entire project

[9] Photo taken by Jeremy Drummond

duration (12 months), so in total would cost right below $6000. This cost is not too high, and after talking to Dominic DeSantis, he informed me that over a day was wasted moving the items from the gym to room 101. This money would have saved the project that extra day and the container would also have been big enough to store other items that might needed to be stored due to the tough weather conditions the site experienced.

[10]The other issue with the container is if there is enough space. It is estimated that to deliver a container, double the length is needed to get the container in its final location. After doing some investigating of the site conditions and space, I found that there is adequate room for the container on the west side of the site, next to the mobile office. There is plenty of room to get the delivery truck onto the site and this space does not get utilized during construction, so having the container there for the project does not affect any other parts of the project. The location of the on-site material storage container can be seen below in Figure 13.

Figure 13-Site Logistics Plan

[10] Created in AutoCAD

Item Procurement

[11]The next issue I discussed with Mrs. Lizzy is the delays the project is incurring due to problems with the window delivery. The project called for the existing windows to remain in the gym/auditorium. These windows needed to be protected during construction and any broken glass panels needed to be replaced. There are many windows on the existing and some can be seen below in Figure 14. When talking with Mr. DeSantis he informed me that in total 16 windows needed to be replaced due to them be already broken and 5 more were needed due to improper care during construction. These windows are a very rare size and only select distributors sell the panels. The original 16 were ordered and the panels were delivered to the site with enough time to not cause any delays. The last 5 panels that got broken during construction are the issue. The original windows did not take long to get delivered because the company was slow at that time. These last 5 windows were forgot about until they needed to be installed. The windows took an extra month to come in, then the original ones. This month caused many delays with getting the building water tight.

Figure 14-Current View of School

Mrs. Lizzy discussed how if the Keystone Group was hired on from the beginning this would not have been an issue. I initially thought the solution would just be to order more windows in the start of the project with the notion that more windows might get broken. Mrs. Lizzy said that is always an option, but for the Duffy case she said the main problem was the last 5 windows was that they were forgotten about until it was too

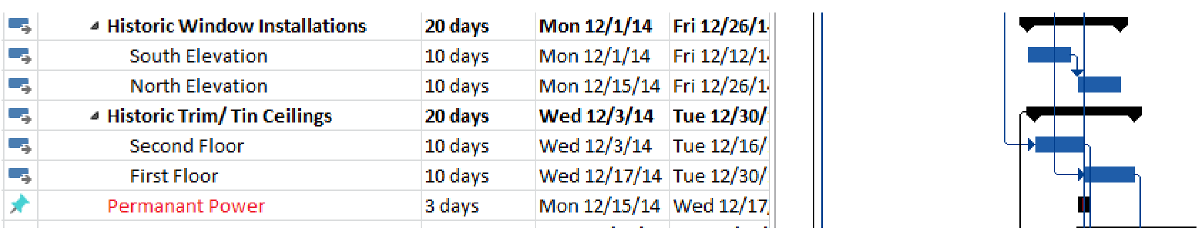
[11] Photo taken by Jeremy Drummond

late. If the Keystone Group was on the project from the start, as soon as another window was broken, they would have already been on the phone ordering more. If the windows were ordered as soon as they were broken they would have had enough time for delivery and that wasted time waiting for the windows would be eliminated.

<u>Proper Storage and Installation</u>

The last issue I discussed with Mrs. Lizzy was the long task times to reinstall the windows, the trim, and the tin ceilings. After reviewing the schedule, I noticed that installing the windows took 10 days each for the first and second floor. On the first and second floor there are only a total of 21 windows being installed. Each window should take a couple hours each. If this is the case, the total time for installing the historic windows should only take around 5 days. This is the same case with the historical trim and tin ceilings. Normally the total time for these activities should be a little over 10 days. For this project, they are given a total of 20 days to complete the task.

[12]When talking with Mr. DeSantis he informed me that the long task durations are to account for finding and repairing the pieces. All the pieces got thrown into the gym and labeled very poorly with only small tags. Many of these tags were either not done completely or fell off during the moving of the pieces from the gym to room 101. Since the labeling is not helping, they decided to double to duration of the activities to account for the tedious task of figuring out what ever piece is and where it belongs. Along with the poor labeling, many pieces needed to be repaired before be installed. This repair needed to be accounted, so extra time was added to the installation tasks. The original schedule can be seen below in Figure 15.



Historic Window Installations	**20 days**	**Mon 12/1/14**	**Fri 12/26/1**
South Elevation	10 days	Mon 12/1/14	Fri 12/12/1
North Elevation	10 days	Mon 12/15/14	Fri 12/26/1
Historic Trim/ Tin Ceilings	**20 days**	**Wed 12/3/14**	**Tue 12/30/**
Second Floor	10 days	Wed 12/3/14	Tue 12/16/
First Floor	10 days	Wed 12/17/14	Tue 12/30/
Permanant Power	3 days	Mon 12/15/14	Wed 12/17,

Figure 15-Historical Installation

After talking with Mrs. Lizzy she explained to me the ways in which the Keystone Group would have been able to help. The one solution that would help a lot is the on-site storage container I have already discussed about. This container would help with the issues of broken pieces or lost labels due to fact the pieces do not get moved or even touched until they are needed back in the building. The next way the Keystone Group could have helped is with their extensive labeling protocol. They are professionals in

[12] Provided by Gary Gardner Construction

labeling historical items and have done it on hundreds of projects. She explained to me that they send their employees to the site and label each piece of historical equipment with a bar code. The bar code gets programmed into a computer. Each bar code corresponds to only one specific piece. When the piece gets put away it gets scanned that it is in storage. Once the piece in needed, the bar code can be scanned again and it will tell you exactly what the piece is and where it has to be installed. Once the piece is installed it gets checked as completed so that all pieces are accounted for. This way of labeling would have saved the project a good amount of time and would have saved a lot of tedious work figuring out where the piece has to go.

5.7 Feasibility Analysis

A feasibility analysis will be helpful in detailing the cost and schedule to decide whether the historical consultant firm is a good option for the Duffy School Addition and Renovation.

Schedule Analysis

The consultant firm can and will do many things to help reduce the total schedule duration. First the firm will help with the removal and storage of the historical pieces that need to be kept and saved to be later reused in the building. The way the consultant firm will label and store the items will saved the overall project and estimated 4 days. The consultant firm will also help with the ordering of items. For the original school, the historical windows are taking a much longer time to get delivered than what was estimated. The consultant firm will make sure all the items are ordered and delivered on time. This will keep the schedule from being delayed 8 days. The firm will also help with proper reinstallation. Reinstalling the windows, trim, border, etc. were estimated to take 20 days. With the consultant firm helping with the reinstall, these historical items should only take 5 days which will save the project another 15 days. Overall the historical consultant firm will save the project an estimated 27 days.

Cost Analysis

After talking to Mrs. Lizzy, she informed me that for a project of this scale, the estimated cost of her firm is around $35,000. This cost includes all items needed, all personnel, and includes all the work explained above, plus much more. This cost seems large for a consultant firm, but when I compared it to previous projects, it turns out this is the average cost.

As discussed above, the total time saved would be around 27 days. This would save the project 27 days of general conditions costs. On average the daily general conditions cost is around $1,400. This would save the project a total of $37,000. As compared with the cost of the consultant firm, the project would save $2,000 if they hire The Keystone Preservation Group.

Table 8- Schedule and Cost Comparison

Comparison Summary		
Item	Consultant Firm	No Firm
Fee	$35,000	x
General Conditions	x	$37,000
Schedule	Save 27 Days	x
Total	$35,000	$37,000
	Save $2,000	

5.8 Conclusion and Recommendation

This analysis looked into if hiring an historical consulting firm for the Duffy School Addition and Renovation is worthwhile. The main issues with the historical requirements for the project is the improper handling and storage of the pieces, the late ordering of pieces, and the poor labeling techniques. The hiring of an historical consulting firm would solve all the issues. The firm would have ordered a storage container for proper storage, would have ordered materials in the correct time frame, and would have helped greatly with the labeling of the historical pieces.

My final recommendation is to hire the Keystone Preservation Group to be a part of the Duffy School Addition and Renovation. The Keystone Group can help with all the issues previously discussed plus can help in many other ways to make sure the project has no delays due to historical requirements put on the building by the municipality.

6.0. Architectural Breadth

About

This breadth with incorporate **Analysis I & II.** In the first analysis the use of solar panels is researched to see if they are a viable option to help offset the costs of the shared spaces in the Duffy School. The second analysis looks into the historical requirements put on the Duffy School. The breadth will look into the historical requirements of putting solar panels on historical buildings.

Historical Requirements

There are many requirements for installing new solar panels on historical buildings. I have researched many of the requirements and will summarize several below.

The first requirement is to try and put the solar panels on new construction. For historical buildings where new additions are proposed, it is encouraged to place the solar panels on the new construction. This is to make sure the solar panels will not change the old building to much but will still be able to use the energy gathered by the array. This requirement was looked at for The Duffy School, so the panels were designed to be installed on the east side of the building on top of the new addition.

The next requirement is to place solar panels in areas that minimize their visibility from public areas. The primary façade of a historic building is often the most architecturally distinctive and publicly visible, and is therefore the most significant and character defining. To the greatest extent possible, the solar panels should be placed to avoid on street-facing walls or roofs, including those facing side streets. This requirement was also looked at for the Duffy School. The Duffy School does not have any roofs that do not face a public street, but the panels were placed in the center of the roof to avoid being seen from close up.

The next requirement is to avoid installations that would result in the permanent loss of significant, character-defining features of the historic building. This means the solar panels should not require any changes to important features of the building. The panels should also be placed to avoid obstructing views of significant architectural features and to not intrude on views of neighboring properties. The main features of the Duffy School is the decorative detailing all around the building. The solar panels will be placed on the roof, so nothing will be changed to make the building lose any of its character. The surrounding buildings are also much smaller than the school, so the solar panels are not obstructing any views.

The last requirement I have looked into is to ensure that the solar panels, support structures, and conduits blend into the surrounding features of the historical building. The solar panels should be placed to match the surrounding building fabric and color. More on different concealment methods for The Duffy School can be read below.

Concealment Methods

To fit with the final requirement for solar panels on historical buildings, the panels must try to blend in or match with the building aesthetics. Different ways to conceal the panels were researched and can be seen below.

The first concealment method is to place the panels flat on the roof. This will eliminate people being able to see them. The panels can be placed flat on their back and can generate energy by taking the sunlight that comes straight down on the panels. For the Duffy School, putting the panels flat on the roof was not a good option because they would not be able to generate enough electricity to power the required areas.

The next form of concealing the panels would be to build a parapet wall around the panels. This wall would be visible from surrounding areas but the panels behind them would not be. The walls would match the existing building and fit into the building character. For the Duffy School this was not an option due to the added weight and cost of building the parapet wall around the new addition.

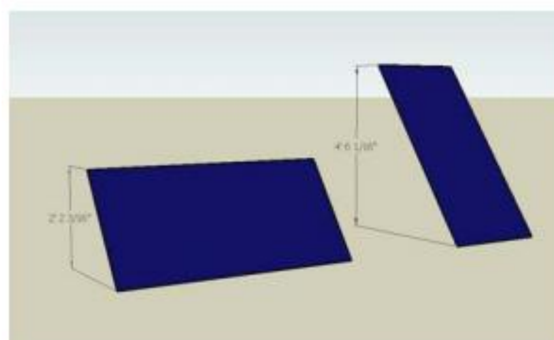


Figure 16-Panel Orientation

[13]The next way to conceal a solar panel that will not be flat on the roof is to turn it sideways. As seen in Figure 14, the tall panels can be turned onto their side in order to minimize the view from public areas. The example on the right shows that a panel that would normally stick into the air over four feet can be placed on its side to only be two feet tall. This can cut the height in half which will greatly limit the visibility of the panels. For The Duffy School, this form of concealment will be used. All the panels will be placed on the new addition so they are more wide than tall. The new addition roof has extra space which will allow for this method to be used. This method will add no cost to the project.

The last concealment method that I researched was painting the solar panels and solar panel equipment. The solar panels could be painted to better match the surrounding building. All the parts of the panels that might be seen from a distance (borders, frame, mounting racks, conduit, etc.) can be painted to camouflage it. If the proper paint color is picked, the solar panels can blend in with the building or surrounding which can make them harder to spot. This concealment method can also be used on The Duffy School. Painting the panels will just ensure that they are hard to see and if they can be seen they match the building and do not look out of place on a historical building. This will only add a small price increase to buy enough paint to fully cover the panels.

[13] http://www.solarpowerpanelsystem.com/

Building Elevations[14]

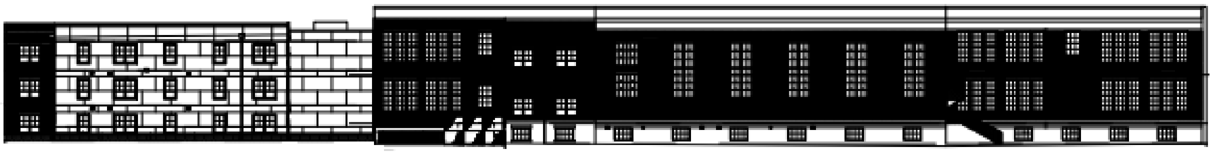


Figure 17-North Elevation (No panels Visible)

Figure 18-South Elevation with Solar Panels

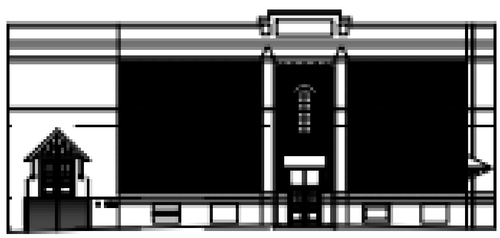


Figure 19-West Elevation (No Panels Visible)

Figure 20-East Elevation with Solar Panels

From the elevations shown above, the visibility of the solar panels is minimal (yellow). The panels are less than 3 feet tall, which makes them hard to see from any angle or view. Standing across West Second Street, pedestrians will be able to see the very top of the panels that stand a little taller than the roof. Due to the small alley and adjacent homes to the north of the sight, there is no place for a pedestrian to stand where they

[14] Provided by Gary Gardner Construction

will be able to see any part of the panels. Due to the existing building on the west side of the solar panel array, there is again nowhere for a pedestrian to stand in which they will be able to see any part of the panels. While standing on Spring Street to the east of the building, pedestrians will be able to again only see the very top of the panels if they can see anything.

Conclusion

After analyzing the historical requirements to put solar panels on The Duffy School Addition and Renovation, it was concluded that with a small price increase, the solar panels can be placed on the building and will be able to fulfil all the requirements. The panels will each be installed on their side and any visible pieces of the panels will be painted to better match the existing building.

7.0 Prefabricated Exterior Wall Panels

7.1 Problem Identification

The Duffy School Addition and Renovation is concerned with keeping the building on the set schedule. The completion date is very important to be able to get the senior citizens moved in. The project is already three weeks behind schedule. To get the project back on schedule either certain activities need to be accelerated or more men need to be added to the project. The entire new addition will have exterior brick masonry that has to match the masonry on the existing building. Stick-building the exterior brick masonry is typically a slow moving activity due to the high level of craftsmanship and the physical strength required to put the materials in place. This activity was originally planned to take 15 days but with the bad weather in the area the activity is now expected to takes 52 days to complete. This delay is hindering the building from being watertight and has pushed the final completion date back a month.

7.2 Proposed Solutions

The Duffy School Addition and Renovation has the opportunity to change from the typical stick-built exterior wall construction into a modular design. An analysis needs to be performed to determine whether the use of prefabricated brick panels will improve the schedule and cost of the building. A feasibility analysis based on cost and schedule will be helpful in evaluating whether prefabricating the building's wall enclosure is a good approach on this project.

After completing the analysis there are several potential solutions that could occur.

- Prefabricating the buildings brick exterior façade could be found to not be feasible due to the raise in cost and the inadequate time saved in the schedule. If this is the case the prefabrication will not be implemented.
- Prefabrication of the building's brick exterior skin could be found to save time and money and therefore should be implemented on the project.
- The costs of designing, transporting, and delivering the prefabricated brick wall panels to the jobsite can be found to be not financially feasible and therefore should not be implemented.

7.3 Background Research

After some research there are three main areas of concern when looking into prefabricating the exterior brick façade. The first area of concern is making sure the aesthetics of the brick façade do not change once the prefabricated system is installed. The brick on the new addition has to be similar to the look of the brick on the existing building. The façade of the new addition has to have a historical feel to it like the brick on the existing building.

The next area of concern is finding out how the prefabricated brick panels will be attached to the structure. Prefabricated brick veneer panels will have to be researched more fully in order to find the right system that will connect to the exterior frame, meet the thermal performance required, and still meet the aesthetic qualities needed on the project.

The last area of concern is figuring out the cost savings or cost added to the project with the manufacturing and installation of the prefabricated system. The cost per square foot to manufacture the panels will be analyzed as well as the cost to get the system to the jobsite. The cost and durations of installing the new panels will also have to be researched more in-depth. Although the prefabrication may greatly reduce the project's schedule, it may not provide the desirable results with regards to the project's costs. Having the brick exterior components built offsite may reduce the labor costs, additional costs might be incurred through the transportation and erection of these components.

7.4 Analysis Procedure

The following procedure was completed to successfully analyze the prefabrication of the exterior wall panels.

- Research different types of prefabricated brick veneer systems.
- Research case studies of similar projects that used prefabrication.
- Determine costs for the original method of construction and productivity rates.
- Examine the building's exterior envelope design and determine the most feasible construction sequence for installing the brick wall panels.
- Calculate costs for off-site prefabrication and off-site staging locations.
- Figure out how it will be installed and the equipment and man power needed.

7.5 Predicted Outcome

Prefabricating the brick exterior envelope of The Duffy School Addition using brick wall panels should result in significant cost and schedule savings. By prefabricating the building enclosure offsite and installing the full panels as they arrive on site, the projects schedule should be reduced while also reducing the amount of labor needed on site which in turn will save money. Additionally, an increase in worker productivity with an easier and faster construction sequence, will also contribute to a shortened construction schedule.

[15]7.6 Current Building Façade

The building enclosure of the Duffy School Addition and Renovation consists of non-structural 3.5" face brick veneer walls with 2x6 wood stud backup. R-21 batt insulation, 1.5" air space, sheathing and air vapor barrier provide the necessary thermal and moisture performances in order to deliver the residents with a comfortable indoor environment. Figure 21 on the right shows the detail of a vertical section of the brick veneer wall. The plan was to begin construction on the south building façade and work their way around the building in a counter-clockwise manner. Starting with the wood stud framing, the consequent trades would follow to have the building air tight by January 2nd, 2015. This process was estimated to be completed in 15

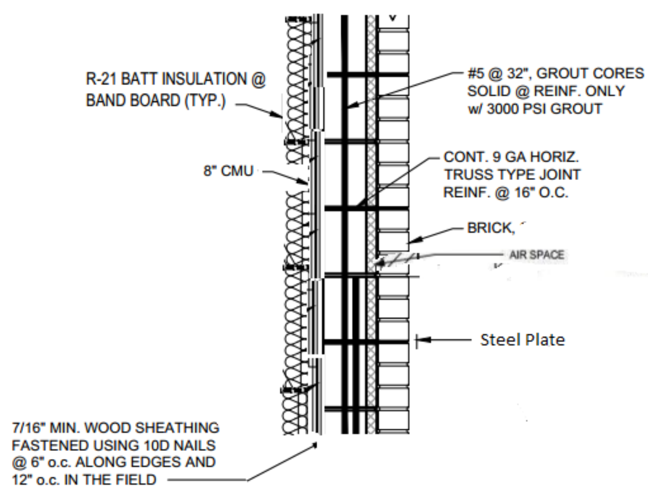


Figure 21-Current Facade

[15] Provided by Gary Gardner Construction

days. The completion of this activity was highly dependent on the weather and productivity of each trade. Any delays in this construction could potentially push back the substantial completion date of the project. The weather did play a large factor with below average temperatures and above average snow fall. The new duration for the completion of the exterior brick façade is 52 days and hopes to be completed by March 3rd, 2015. The use of heaters and tents in small areas of the façade were needed in order to move on with the construction.

7.7 Prefabricated Alternatives

When looking into a precast concrete panelized system for a building's exterior envelope there are a numerous amount of options, each with unique aesthetic treatments to achieve a desired appearance. For this report, architectural inset thin-brick precast panels can create the specific appearance that is required by the owner. Thin-brick manufactures can provide real brick aesthetics with the benefit of fast installation.

For the Duffy School Addition and Renovation SlenderWall Architectural Precast Concrete Brick Panels will be investigated. SlenderWall is a light architectural precast concrete system. The precast system consists of a two inch reinforced architectural precast concrete exterior layer, with the inside is composed of sixteen gauge, six inch galvanized steel studs that are spaced vertically at two foot off center.

[16]The connections are gravity connections, spaced at four feet on center with tie backs at six feet on center to hold the panel to the structural wood frame of the building. To secure the architectural concrete to the steel frame, epoxy-coated stainless-steel welded anchors are used which create a half inch air space between them. This air space allows or a better thermal performance. The typical weight for a SlenderWall panel is around 28 lbs. per square foot, which is significantly less than the traditional brick.

Figure 22-SlenderWall

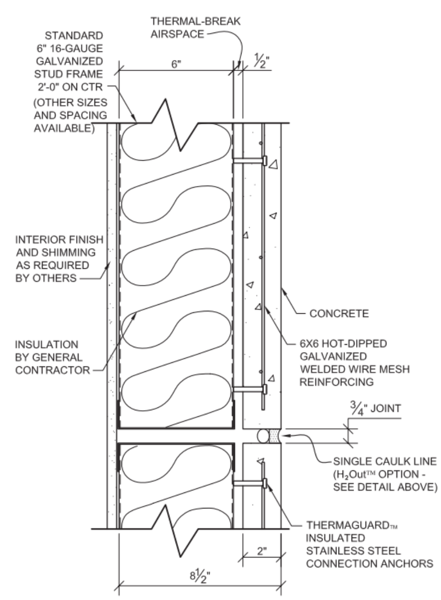


Figure 23-SlenderWall Detail

[16] Slenderwall.com

7.8 Prefabricated Panel Design & Installation Process

SlenderWall Architectural Precast Concrete Brick panels offer the best between all other panels. They have real brick aesthetics with the benefit of fast installation and low cost escalation through precast panel prefabrication. Following the prefabricated panel selection, an evaluation will be performed for The Duffy School Addition and Renovation.

Prefabricated Panel Design

One of the main benefits of assembling panels under a controlled environment is that it allows for safer and more comfortable working conditions. The weather has no effect in the controlled environment. Due to this, the quality and productivity are greatly increased because the harsh weather like rain, snow, and cold temperatures do not affect the manufacturing process. As well as not being affected by the weather, assembling the wall panels in a plant allows for a lot of flexibility. SlenderWall panels come in a wide range of panel sizes and designs that can be easily meet a project's needs.

To install the SlenderWall panels a mobile crane is necessary. For a small 2-3 story building, either a 90 ton or 100 ton crane is needed with four crew members and the crane operator. The panels need around four months to be fabricated, so ordering these ahead of time is crucial to prevent any delays in the schedule of the project. The SlenderWall panels can be installed once the wood frame is erected and the floors are finished.

When talking with a representative from the Smith-Midland Corporation, Mike Schwartz, he explained that the cost per square foot can range depending on the type of finish, complexity of the panel, and repetition. When I explained what was needed for the Duffy School Addition, he estimated the panels to cost around $32 per square foot. In these costs are the exterior studs, sheathing, vapor barrier, bricks, finishes, any openings, and the cost of transportation.

The Duffy School façade was not designed for the use of prefabricated panels, which resulted in some unique challenges when trying to break down the panel layout. A total of 16 precast panels will need to be used in the design of the building's façade. The panels will be placed vertically from the foundation to the roof, with a maximum height of 34 feet. The panels will have a consistent width of 12 feet. The window and door locations are similar for most of the building, but there will need to be 4 different panel types to fit on the building. The first panel (yellow) type will consist of three double hung windows and will be a height of 32'4", the second panel type (red) consists of three single hung window at a height of 31 feet, and the third panel type (green) will consist three single hung windows at a height of 32'4". The last type (blue) will consist of three single hung windows and a single door opening at a height of 32'4". As seen below, each panel is a different color. There need to be 8 of the first panel, 3 of the second panel, 4 of the third type of panel, and only 1 of the final type.

[17]

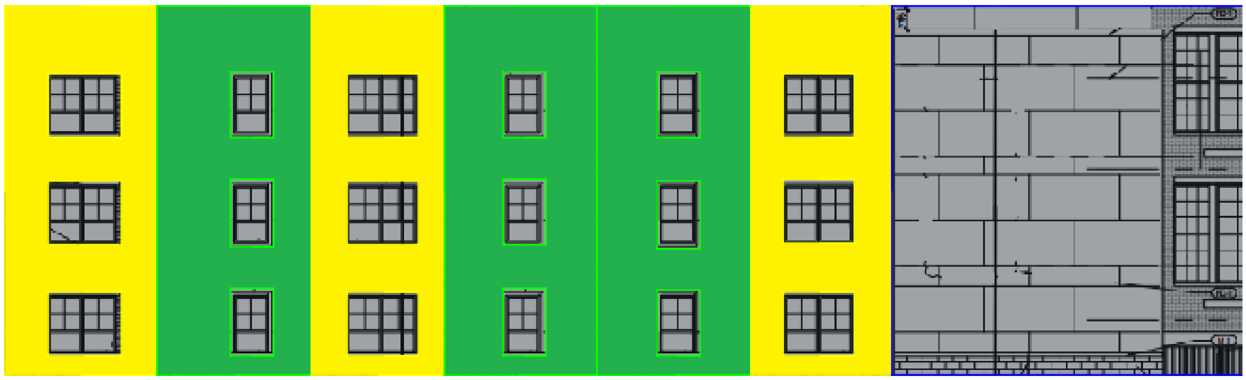


Figure 24- North Elevation w/ Panels

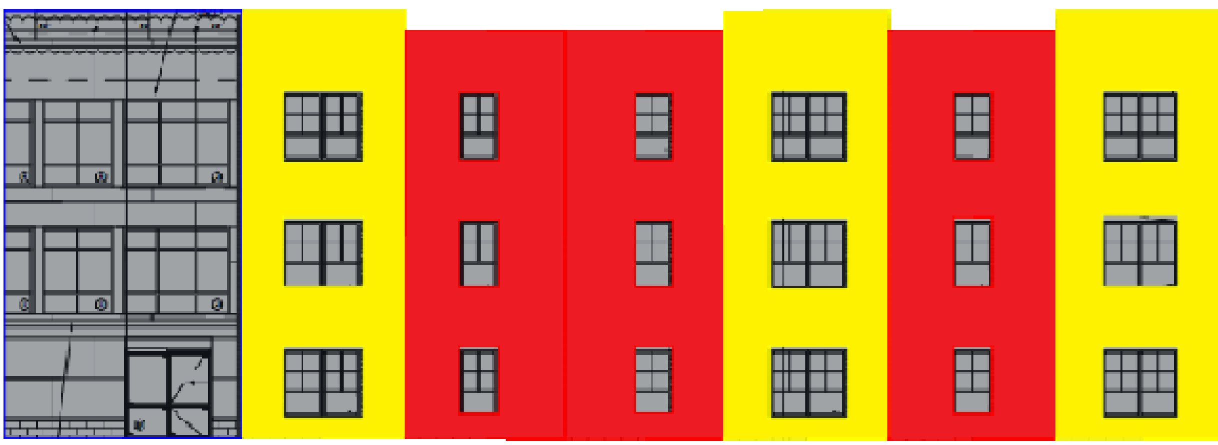


Figure 25- South Elevation w/ Panels

[17] Created by Jeremy Drummond

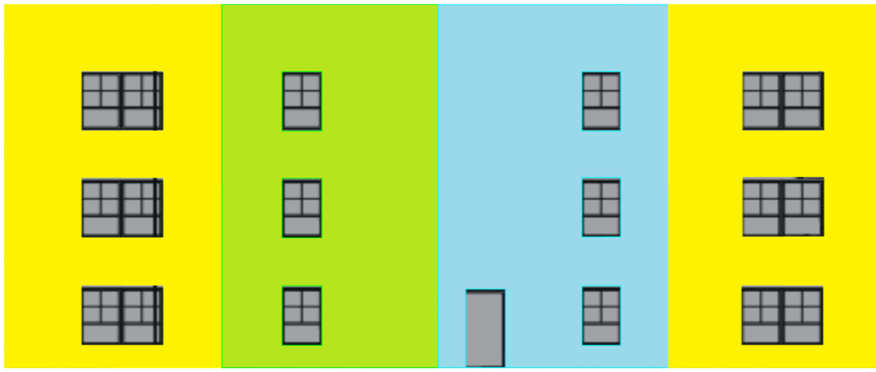


Figure 26- East Elevation w/ Panels

Table 9-Panel Takeoffs

Precast Panel Takeoffs												
Panel Designation	Width (ft.)	Height (ft.)	Openings	Opeing Area (SF)	Joint Sealant (LF)	East Façade	South Façade	North Façade	Total Quantity	Total Panel Area (SF)	Average Cost/SF	Total Cost
A-1	12	32.33	3 x W2	90	87.8	2	3	3	8	388	$32	$99,328
B-1	12	31	3 x W1	45	85.3		3		3	372	$32	$35,712
C-1	12	32.33	3 x W1	45	87.8	1		3	4	388	$32	$49,664
D-1	12	32.33	3 x W2, D1	111.5	87.8	1			1	388	$32	$12,416
Total					348.7	4	6	6	16	1536	$32	$197,120
Anitcipated Schedule Duration (Days)						0.5	0.75	0.75	2			

Opening	W1	W2	D1
Area (SF)	15	30	21.5

<u>Transportation and Delivery</u>

[18]One of the main factors in choosing SlenderWall as the manufacturer for the prefabricated brick panels was its close location to the project site in Florence Township, NJ. The panels are being fabricated at an estimated distance of 200 miles from the site, with an expected travel time around 4 hours. The recommend route can be seen on the right.

Figure 25-Delivery Map

The Virginia, Maryland, and New Jersey shipping permit regulations were found using wideloadshipping.com. The state of Virginia

[18] Googlemaps.com

requires a permit for hauling loads over 8’6” wide but does not require a pilot car for loads under 12 feet wide. The state of Maryland also requires a permit for loads wider than 8’6” and does not require a pilot car. Lastly, the state of New Jersey has the same requirements as Virginia and Maryland. Due to restrictions the hauling has to take place between sunrise and sunset from Monday-Saturday.

Site Logistics

[19]The site logistics is a concern on any construction project. It takes planning upfront to make sure everything on the site will be able to run smoothly and not affect the flow of construction for other trades and tasks. The current site layout for the Duffy School Addition and Renovation will be able to accommodate the delivery and installation of the prefabricated wall panels. The panels will not affect the site logistics if they get delivered right when needed. There is not space to store the panels, so they must get delivered and erected in a close time period. The delivery trucks will park on West Second Street on the south side of the building. The wall panels will be picked up directly from the truck bed and hoisted into place by the crane. It is

Figure 26-Delivery Site Logistic Plan

[19] Created by Jeremy Drummond

estimated to take around an hour for each panel to be hoisted and installed which will allow all 16 panels to be placed in two days. The site layout can be seen above, with the delivery trucks staying off the site on the street.

Waste

With typical stick-built construction a lot of construction waste is generated. Since the panels will be constructed offsite, the amount of waste will be greatly reduced. In addition, chemicals will not be needed as they would be with typical stick-built construction in cold temperatures. Using prefabricated panels will also help with the New Jersey "Green Point System" (as explained above in Section 2.6).

7.9 Feasibility Analysis

A feasibility analysis will be helpful in detailing the cost and schedule to decide whether the proposed prefabricated panel system is a good option for the Duffy School Addition and Renovation. A quantity takeoff was performed to calculate the total number of prefabricated panel's needed and square footage.

Schedule Analysis

One of the main reasons prefabrication is being considered for this project is to accelerate the schedule. It has already been noted that for the panels to be fabricated and delivered in time there is a four month period needed. Mike Schwartz informed me that 800 SF of panel can be manufactured each day which is around 1 panel per day. For the amount of panels needed on this project, the manufacturer would spend around 16 days to fabricate all the panels.

As stated earlier each panel takes around one hour to be installed. This would allow for 8 panels to be erected in a typical day. This would make the erection of the brick façade last at most 3 days (with some time added for learning curve). The durations were also rounded up to account for breaks for lunch and rest time.

Table 10-Panel Durations

Panel Installation Durations			
Elevation	Panel QTY.	Duration	Adjusted Duration
South	6	.75 Days	1 Day
North	6	.75 Days	1 Day
East	4	.5 Days	.75 Days
Total	**16**	**2 Days**	**2.75 Days**

Compared to the original duration of 52 days, utilizing precast brick panels can significantly reduce the building's exterior wall construction duration. The brick installation was shortened by 49 days. This allowed for other activities to be completed earlier than what was planned.

[20]A new proposed schedule can be seen below in Figure 27. The schedule remains the same for all activities prior to the brick veneer, as the proposed system would not affect these activities.

New Building	**173 days**	**Wed 6/25/14**	**Fri 2/20/15**
Building Frame	**82 days?**	**Wed 6/25/14**	**Thu 10/16/14**
Ground Floor	10 days	Tue 11/4/14	Mon 11/17/14
First Floor	15 days	Wed 11/12/14	Tue 12/2/14
Second Floor	9 days	Tue 12/2/14	Fri 12/12/14
Brick Install	3 days	Mon 12/15/14	Wed 12/17/14
Window and Door Installation	10 days	Mon 12/22/14	Fri 1/2/15
Exterior Finishes	25 days	Mon 1/5/15	Fri 2/6/15
Permanent Power	3 days	Thu 12/18/14	Mon 12/22/14

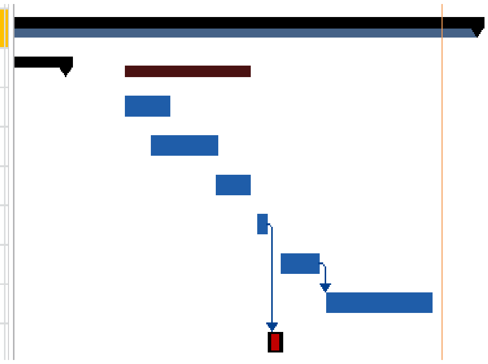


Figure 27- New Prefab Panel Schedule

After the changes to the original schedule, The "Permanent Power" milestone was pushed up to December 22, 2014. This allows for some interior work to begin earlier in the project. Shortening the brick installation by 49 days allowed the overall schedule to be shortened by 15 days. This is due to issues with other aspects of the building. Some of these issues include problems with the windows in the existing building and due to the historical restrictions put on the Duffy School Addition and Renovation.

Cost Analysis

Now that the schedule impacts have been determined, a cost analysis will be performed to determine if the precast panels are feasible for this project. A direct cost comparison between the proposed and existing enclosure was performed. From Mike Schwartz, the average cost of the prefabricated brick panels (including material, delivery, and installation) is $32/SF. The actual cost of the brick masonry wall is $10.47/SF, and was taken from "The Schedule of Values" provided to me by Sam Leone of Conifer LeChase Construction.

[20] Provided by Gary Gardner Construction

Table 11- Panel Cost

Building Enclosure Construction Cost Comparison					
Material	Total (SF)	Prefabricated Panels		Traditional Brick	
		Cost/SF	Total	Cost/SF	Total
Exterior Face Wall	6,200	$32.00	$198,400.00	$10.47	$64,914.00
Interior Components	6,200	$18.73	$116,126.00	$18.73	$116,126.00
Insulation	6,200	$1.65	$10,230.00	$2.89	$17,918.00
Caulking	1,190	$2.18	$2,594.20	x	x
Transportation	x	Included	Included	x	x
Erection Equipment	x	Included	Included	x	$35,026.00
Total		**$54.56**	**$327,350.20**	**$32.09**	**$233,984.00**

As seen above, the precast system costs over $93,366 more than the traditional brick veneer currently being used. This estimate only takes into account the cost of material, labor, and equipment needed to construct each assembly. Due to some unexpected weather, a more accurate cost estimate is needed which will take into account changes in the general condition costs.

The general conditions estimate would change due to the added heaters and tents needed for the traditional brick install due to the cold weather. Completing the project earlier than originally planned would save 15 days of project personnel, field offices, and operating expenses. That results in a savings of $20,526. Table 10 summarizes the total cost impact of implementing precast wall panels on the Duffy School Addition. As seen, the precast panels will increment the total project cost by $72,840.20.

Table 12- Cost Comparison

Cost Comparison Summary		
Item	Prefabricated Panels Total Cost	Traditional Brick Total Cost
Cost of Assembly	$327,350.20	$233,984.00
General Conditions Cost	$466,630.00	$487,156.00
Total	**$793,980.20**	**$721,140.00**

7.10 Conclusion and Recommendation

This analysis compared an alternative precast modular system to the current stick-built exterior wall construction for The Duffy School Addition. The original construction of the building envelope took a total of 52 days and required a large amount of labor hours, scaffolding, and was very dependent on the weather. Prefabricating the exterior façade allowed the opportunity to improve the schedule and cost of the building. Through extensive research and by talking to industry professionals, it was determined that SlenderWall Architectural Precast Panels would be the best alternative for the building wall prefabrication.

The design required a total of 16 precast panels spanning the buildings total height. The panels would be fabricated in VA which is an estimated distance of 200 miles from the site, and transported directly to the crane for erection. The current site layout was able to accommodate the delivery and installation of the prefabricated wall panels, so therefore no major changes needed to be done.

Implementing precast panels costs an additional $73,000 to the project budget, and would reduce the project schedule by 3 weeks.

After a lot of consideration of the impact on the cost and schedule, it was determined that it might not be in the owner's best interest to purse this alternate construction method. I would not recommend the use of prefabricated walls over the traditional brick veneer system, as the increased cost and planning required outweigh the savings in the schedule. There is only a certain budget allocated for the affordable housing and the extra cost of the prefabricated system would go over this.

8.0 BIM Utilization

8.1 Problem Identification

The schedule is a main concern for the owner. The project needs to finish on time so the residents can move in. One main issue that has held the project up is that the as-built drawing for the original school is not correct. Doorways are feet from where they are supposed to be, windows were not in the correct locations, dimensions were missing, etc. There was a lot of wasted time when the project team and the architect were trying to communicate and collaborate due to the many issues of the incorrect as-built drawings. The as-built being incorrect has caused over 72 RFIs (request for information) and around 24 ASI's (architects supplemental information). All these RFI's and ASI's take time to get answers, which can cause major schedule delays.

The implementation of BIM will also help the owner with operation and maintenance after the building is turned over. As discussed above the building will include photovoltaic panels which will require maintenance. The implementation of BIM will greatly help to solve this problem.

8.2 Proposed Solutions

A possible solution to help with the many discrepancies in the as-built drawings and to help with future maintenance could be the use of Building Information Modeling (BIM). It could be used to create 3D models to find possible as-built drawing issues earlier in the project. This will allow for the issues to be corrected before construction starts. A 4D model could also be used to display to the project team the delivery and installation of the prefabricated exterior walls as seen in **Analysis 3**. A 4D model will be useful and help demonstrate the procedure to the project team and subcontractors.

After completing the analysis there are several potential solutions that could occur.

- The cost of creating the 3D and 4D model is too high and outweighs the costs saved from the use of BIM. If this is the case, BIM will not be utilized.
- The amount of time saved by limiting RFI's is substantial and therefore BIM should be utilized.
- The amount of time added by the creation of the 3D and 4D model is more than the time saved and therefore BIM should not be utilized.

8.3 Background Research

BIM has many uses in the construction industry. BIM can be used for 3D coordination, site utilization planning and analysis, structural analysis, digital fabrication, and facilities management. Since the drawings were never put into 3D format, clash detection could not be used and this resulted in the increased amount of RFI's on the project.

My main focus will be utilizing 3D and 4D coordination. BIM could assist in the coordination of the different systems and would have been able to find errors in the as-built drawings a lot earlier for the project. The application of BIM could have benefited the overall project costs and schedule.

The Pennsylvania State University BIM Execution Planning Guide will be used to facilitate the analysis.

8.4 Analysis Procedure

The following procedure should be completed to successful analysis the use of BIM on the Duffy School Addition and Renovation.

- Determine the different uses of 3D models for coordination.
- Look into reasons the owner decided to not use BIM initially.
- Evaluate the costs of a 3D and 4D model.
- Look into the estimated costs associated with change orders.
- Evaluate the duration of creating the 3D and 4D model.
- Determine possible schedule savings by limiting the number of RFI's.
- Research facility maintenance scenarios.

8.5 Predicted Outcome

With the use of 3D coordination the predicted outcome for this analysis is that BIM will be very useful. A 3D model of the existing building will help substantially by preventing RFI's and change orders. With the 3D model complete, clash detection software could be used which will again limit the amount of RFI's and will save time for the project. The use of a 4D model for **Analysis 3** is expected to be useful in displaying the procedure and benefits of prefabricated exterior wall panels. The use of BIM will also be beneficial with **Analysis 1** to help the owner with future maintenance of the photovoltaic panels.

8.6 BIM Utilization

Table 13- BIM Uses

X	Plan	X	Design	X	Construct	X	Operate
	Programming		Design Authorizing	X	Site Utilization Plan	X	Building Maintenance
X	Site Analysis	X	Design Reviews	X	Construction System		System Analysis
			3D Coordination		3D Coordination		Asset Management
			Structural Analysis		Digital Fabrication		Space Tracking
			Lighting Analysis		3D Planning		Disaster Planning
			Energy Analysis		Record Modeling		Record Modeling
			Mechanical Analysis				
			Other Analysis				
		X	Sustainability				
			Code Validation				
X	4D Modeling		4D Modeling	X	4D Modeling		4D Modeling
X	Cost Estimation	X	Cost Estimation	X	Cost Estimation	X	Cost Estimation
	Existing Conditions	X	Existing Conditions	X	Existing Conditions	X	Existing Conditions

When looking at BIM for this project, several areas could have been improved with the use of BIM. These areas include 3D coordination, 4D modeling and facility maintenance. Some typical BIM programs used could be programs such as AutoCAD Revit for 3D modeling or a program such as Navisworks could be used for 4D modeling and facility maintenance.

Before implementing BIM on a project, the project team, workers, and owner will need to be able to use the programs to take full advantage of BIM's capabilities. Training sessions can be used on site for the project team and workers, which will allow them to fully understand and use BIM to its fullest extent. This training will not necessarily teach the workers how to draw and model in Revit or Navisworks, but will show them how to properly navigate through the model to find whatever they need. These training programs are extremely beneficial when implementing BIM on a project.

BIM for the Duffy School Addition and Renovation was not utilized at all. This does not mean that it could not have been beneficial. The benefits can be seen when applied to **Analysis 1 and 3.** Each of these analyzes would benefit from BIM in many ways. Three of the main benefits would be displaying a 3D model to help find the issues with the as-built drawings earlier on in the project and a 4D model to help with the phase planning of **Analysis 3** and the future maintenance required for **Analysis 1.**

3D Modeling

One of the main issues with the Duffy School Addition and Renovation is the incorrect as-built drawings. For the renovation, all the existing classrooms are being transformed into livable apartments for senior citizens. The project team relied on these as-builts to be correct when they worked in the existing area.

When talking with the project manager, Dominic DeSantis, he informed me the as-built was incorrect in many places. The location of existing doors where not shown correctly, multiple columns where feet from the documented location, windows that were shown on the drawing did not actually exist in the school, etc. These errors resulted in a large amount of RFI's and ASI's. He estimated over 100 of these combined were needed for the project in the first couple weeks of construction. Every issue needed to be documented and sent to the architect for approval. The turnaround period for this was not quick and Dominic estimated around 3 weeks to finally receive an answer. This caused many delays in the project.

If a 3D model was created, the issues with the as-built drawings would have been found much earlier on. When the designer using Revit was comparing the as-built to the actual building when he was making the model, he would have found the issue. The 3D model would have been created before the project even started, so all the issues would have been found before and construction took place. Finding these issues would have limited the amount of RFI's and ASI's greatly.

4D Modeling

A 4D model could have been used to effectively show the construction sequence and the different phases of construction for the prefabricated exterior wall panels. This would identify space and workspace conflicts and would be able to resolve these issues ahead of the construction process.

The construction of the prefabricated wall panels revolve around activities that involve large equipment and materials. A 4D model is a great way to show how the new construction activity will work. **Analysis 3** implements large equipment, new delivery tactics, and installation techniques in order to improve the overall schedule of the project. This equipment and new delivery method can be displayed accurately and to scale with the use of BIM.

In a 4D model, the equipment needed in **Analysis 3** can clearly be displayed in its exact location and uses for the prefabricated panel installation. BIM can be used to show the basic aspects of the panel installation while still explaining how the phase will flow with the rest of the construction activities.

The 4D model can clearly display how the panels will be installed around the addition with the use of different colors. The model can also show the locations of the delivery trucks, the equipment needed, the construction trailers and the laydown area for the materials.

The use of a 4D model can also help create maps for each phase of construction that can be set up around the site on the inside of the building and or the exterior of the building. These maps will allow for workers and pedestrians to see which activity is going on and the current traffic plan around the site. This will be beneficial for **Analysis 3** for when one lane of traffic needs to be closed for the delivery of the wall panels. These maps can also help keep pedestrians out of danger zones during the entire construction process but specifically when the prefabricated exterior wall panels are being installed. This phase requires the movement of large pieces of equipment and materials so the safety hazards are increased.

Facility Maintenance

Once completed the Duffy School Apartments will have 13 full time staff members. These staff members will have different jobs but some of them will be in charge of facility maintenance. With facilities management the owner has different ways of approaching issues to the building. One option known as Space/Real Estate Management is where all the space is clearly defined and anyone looking at the model can tell exactly what goes in the space and what goes on in the space. The second option is Project Management, which helps future contractors do any renovations that may occur. The last option and the one that would be used for The Duffy School is Asset Management which helps with the equipment maintenance in the building.

Asset Maintenance is ideal for the solar panels discussed in **Analysis 1.** These staff members will not have a vast knowledge of how the solar panels work and the maintenance required for them. With asset maintenance, if a problem occurs with the panels, the staff will be alerted to what the problem is and where exactly it is located. With some training about how to navigate around the 4D model, the staff members will be able to understand all the components of the solar panels and if there is an issue they will be able to locate it and fix.

By having the solar panels linked into BIM, is also makes planning easier. BIM can accurately keep track of when each piece of equipment needs to be checked or inspected to make sure they continue to work properly. Also with the asset maintenance, the manuals and specifications can be programmed right into the model. This will allow for the staff members to not have to dig around for the paper copies of the manual and specifications but instead will have the digital copies only a click away.

8.7 Conclusion and Recommendation

In conclusion the implementation of BIM has many potential benefits to help with coordination, phasing and facility maintenance. Using BIM can be very useful in limiting the amount of time wasted with RFI's, can help with the phasing and construction activities associated with the prefabricated wall panel installation, and can aid with future maintenance of the solar panels.

The final recommendation is to implement the three parts of BIM for this project. BIM can help with many other things but for this project, using BIM to a small scale can be very beneficial and should be implemented.

9.0 Final Recommendations

Analysis 1- Rooftop Solar Panels

This analysis focused on improving the energy efficiency of the common/shared spaces in the Duffy School. The area of investigation was to see if solar panels can be placed on the building to help pay for the energy consumed in the common areas. This analysis investigated the different solar panels available, their ease of installation and maintenance, and the associated costs. The overall cost of the solar panels was calculated and came out to $69,270.76 and the duration to install the panels was found at around 19 days. With the total cost and installation of the panels being low, adding solar panels to the building was recommended.

Analysis 2- Historical Requirements

This analysis focused on the schedule improvements with the use of hiring an historical consultant for all the historical components of the school. The Duffy School Addition and Renovation needed to follow numerous historical guidelines according to the Duffy Urban Renewal Program and by Florence Township. These guidelines required many pieces of the existing school to be carefully removed and stored so they can be reused in the new apartment building. With the amount of time saved, I recommended hiring an historical firm.

Analysis 3- Prefabricated Exterior Wall Panels

This analysis focused on schedule improvements with the use of pre fabricating the exterior brick veneer. The Duffy School's new addition enclosure consists primarily of brick veneer façade and a small curtain wall. Covering large percentages of the building enclosure, the opportunity of using prefabricated panels or modular façade systems potentially accelerated the schedule and reduced labor costs. The total duration to install the panels was found to be right under 3 days and the total cost was found to be $72,840 more than traditional stick built. With the large cost added to the project, I did not recommend using prefabricated exterior panels.

Analysis 4- BIM Utilization

This analysis focused on the use of BIM to improve the project. BIM was not used at all on this project but could have been used to improve the project in several ways. BIM could have been used from the start to turn the original school building drawings into electronic files. Having an electronic model of the building will have been able to show the problems with the as-built. BIM has many more uses, but for this project I recommended implementing BIM at a small scale.

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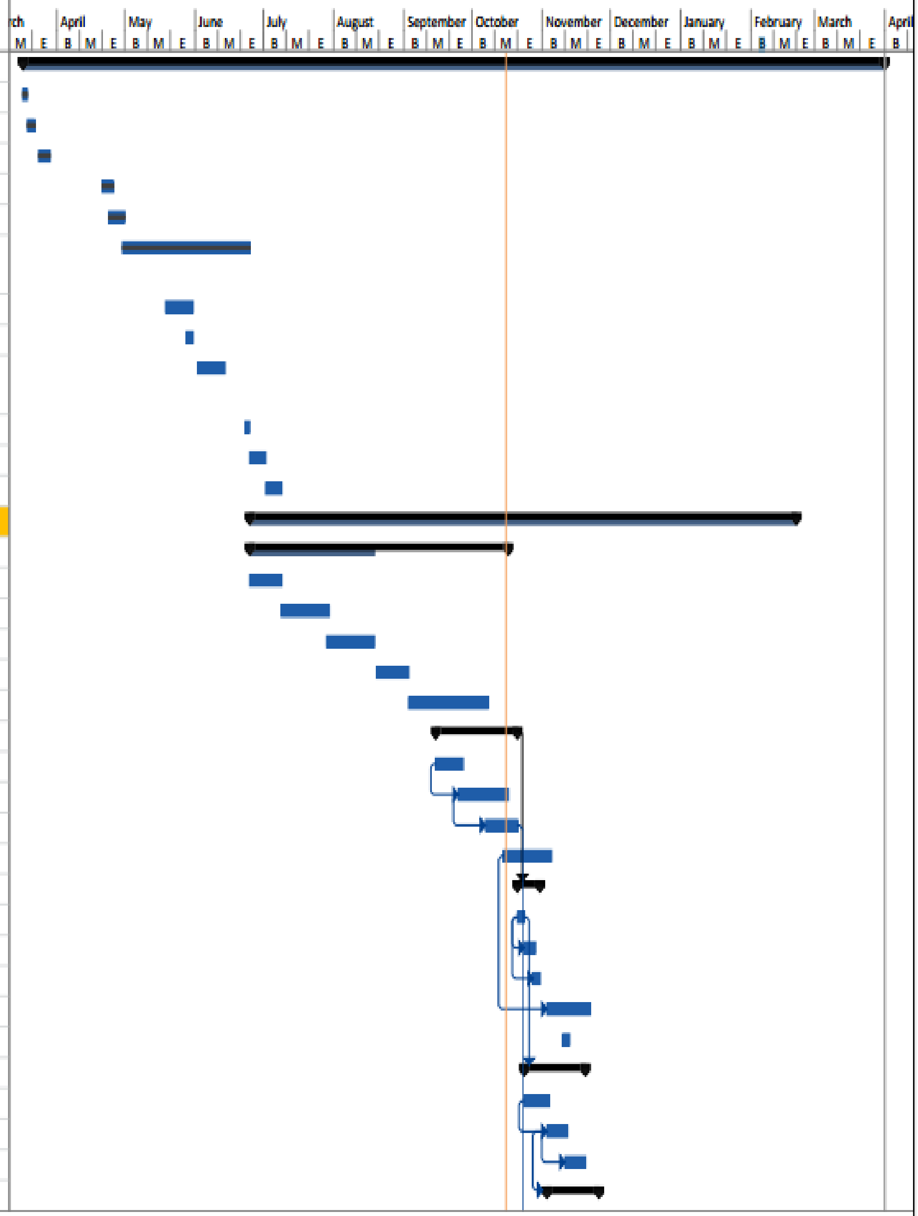
Appendix A: Original Project Schedule

ID	Task Mode	Task Name	Duration	Start	Finish
1		Duffy Schedule	272 days	Mon 3/17/14	Tue 3/31/15
2		Secure Site	2 days	Mon 3/17/14	Tue 3/18/14
3		Mobilization	3 days	Wed 3/19/14	Fri 3/21/14
4		Abatement of House	5 days	Mon 3/24/14	Fri 3/28/14
5		Site Clearing and Grubbing	5 days	Mon 4/21/14	Fri 4/25/14
6		Demolition of Parking East	5 days	Thu 4/24/14	Wed 4/30/14
7		Abatement and Demo of Exisiting Building	40 days	Wed 4/30/14	Tue 6/24/14
8		Footings and Foundations	10 days	Mon 5/19/14	Fri 5/30/14
9		Demolition of 1990's Addition	3 days	Wed 5/28/14	Fri 5/30/14
10		Underpinning of Exisiting Foundations	10 days	Mon 6/2/14	Fri 6/13/14
11		Floor Slab Insulation	2 days	Mon 6/23/14	Tue 6/24/14
12		New Elevator Footing	5 days	Wed 6/25/14	Tue 7/1/14
13		Building Link Steel Installation	5 days	Wed 7/2/14	Tue 7/8/14
14		**New Building**	**173 days**	**Wed 6/25/14**	**Fri 2/20/15**
15		**Building Frame**	**82 days?**	**Wed 6/25/14**	**Thu 10/16/14**
16		Ground Floor	10 days	Wed 6/25/14	Tue 7/8/14
17		First Floor	15 days	Wed 7/9/14	Tue 7/29/14
18		Second Floor	15 days	Tue 7/29/14	Mon 8/18/14
19		Window and Door Installation	10 days	Wed 8/20/14	Tue 9/2/14
20		Exterior Finishes	25 days	Wed 9/3/14	Tue 10/7/14
21		**MPE Rough**	**26 days**	**Mon 9/15/14**	**Mon 10/20/14**
22		Second Floor	10 days	Mon 9/15/14	Fri 9/26/14
23		First Floor	10 days	Thu 9/25/14	Thu 10/16/14
24		Ground Floor	10 days	Tue 10/7/14	Mon 10/20/14
25		Brick Install	15 days	Wed 10/15/1	Tue 11/4/14
26		**Building Insulation**	**8 days**	**Tue 10/21/14**	**Thu 10/30/14**
27		Second Floor	3 days	Tue 10/21/14	Thu 10/23/14
28		First Floor	3 days	Fri 10/24/14	Tue 10/28/14
29		Ground Floor	3 days	Tue 10/28/14	Thu 10/30/14
30		Siding Installation	15 days	Mon 11/3/14	Fri 11/21/14
31		Storefront Installations	3 days	Mon 11/10/1	Wed 11/12/14
32		**Drywall Installations**	**19 days**	**Fri 10/24/14**	**Wed 11/19/14**
33		Second Floor	7 days	Fri 10/24/14	Mon 11/3/14
34		First Floor	7 days	Mon 11/3/14	Tue 11/11/14
35		Ground Floor	7 days	Tue 11/11/14	Wed 11/19/14
36		**Unit Trim/ Unit Door Installation**	**17 days**	**Mon 11/3/14**	**Tue 11/25/14**

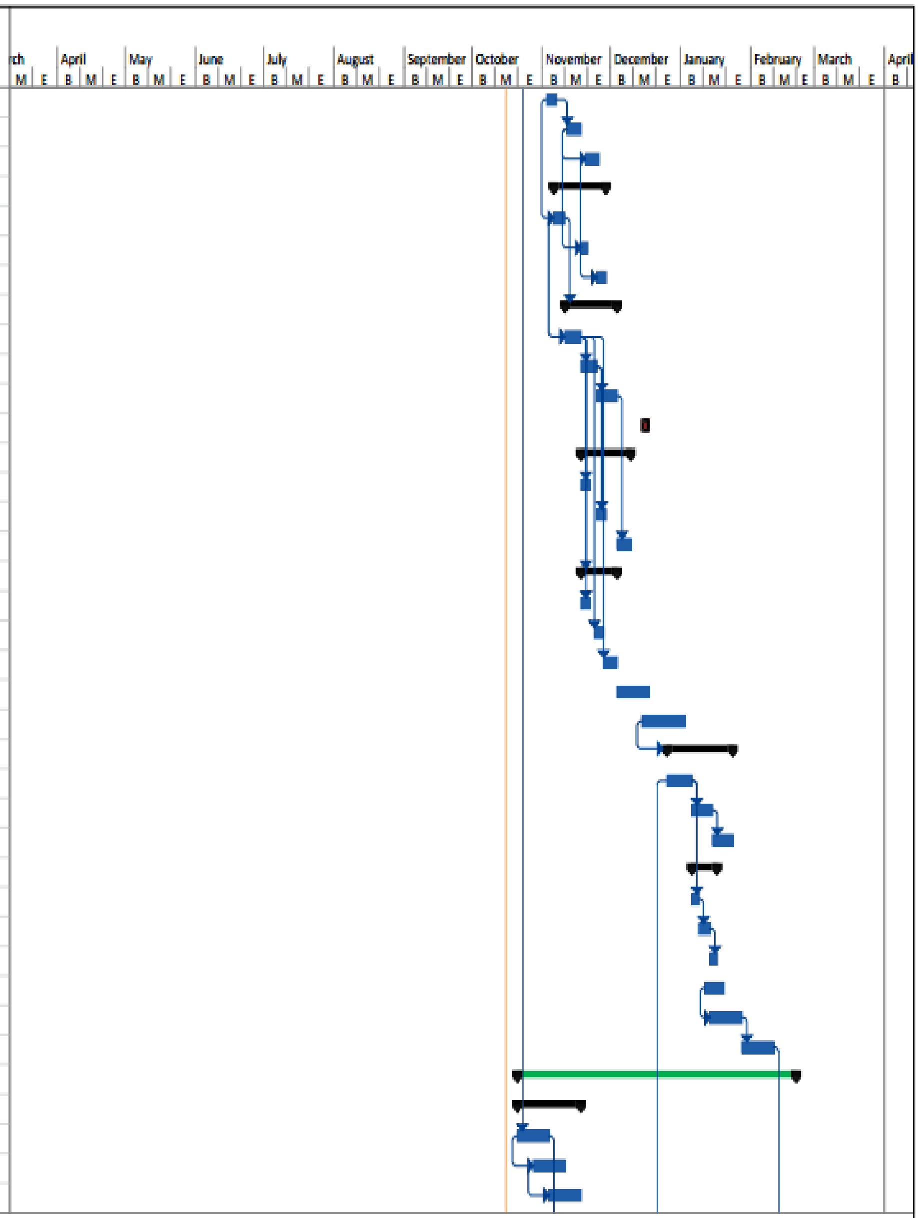


Project: Duffy Recovery Schedule

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

Page 1

ID	Task Mode	Task Name	Duration	Start	Finish
37		Second Floor	4 days	Mon 11/3/14	Thu 11/6/14
38		First Floor	4 days	Wed 11/12/1	Mon 11/17/14
39		Ground Floor	4 days	Thu 11/20/14	Tue 11/25/14
40		**Unit Paint**	**17 days**	**Thu 11/6/14**	**Fri 11/28/14**
41		Second Floor	3 days	Thu 11/6/14	Mon 11/10/14
42		First Floor	3 days	Tue 11/18/14	Thu 11/20/14
43		Ground Floor	4 days	Tue 11/25/14	Fri 11/28/14
44		**Hard Surface Flooring**	**17 days**	**Tue 11/11/14**	**Wed 12/3/14**
45		Second Floor	5 days	Tue 11/11/14	Mon 11/17/14
46		First Floor	5 days	Tue 11/18/14	Mon 11/24/14
47		Ground Floor	7 days	Tue 11/25/14	Wed 12/3/14
48		Permanent Power	3 days	Mon 12/15/1	Wed 12/17/14
49		**HVAC Heater Installations**	**16 days**	**Tue 11/18/14**	**Tue 12/9/14**
50		Second Floor	4 days	Tue 11/18/14	Fri 11/21/14
51		First Floor	4 days	Tue 11/25/14	Fri 11/28/14
52		Ground Floor	4 days	Thu 12/4/14	Tue 12/9/14
53		**Kitchen Installations**	**12 days**	**Tue 11/18/14**	**Wed 12/3/14**
54		Second Floor	4 days	Tue 11/18/14	Fri 11/21/14
55		First Floor	4 days	Mon 11/24/1	Thu 11/27/14
56		Ground Floor	4 days	Fri 11/28/14	Wed 12/3/14
57		Appliance Installations	10 days	Thu 12/4/14	Wed 12/17/14
58		Plumbing Installations	15 days	Mon 12/15/1	Fri 1/2/15
59		**MPE Finish**	**21 days**	**Fri 12/26/14**	**Fri 1/23/15**
60		Second Floor	7 days	Fri 12/26/14	Mon 1/5/15
61		First Floor	7 days	Tue 1/6/15	Wed 1/14/15
62		Ground Floor	7 days	Thu 1/15/15	Fri 1/23/15
63		**Carpet Install**	**9 days**	**Tue 1/6/15**	**Fri 1/16/15**
64		Second Floor	3 days	Tue 1/6/15	Thu 1/8/15
65		First Floor	3 days	Fri 1/9/15	Tue 1/13/15
66		Ground Floor	3 days	Wed 1/14/15	Fri 1/16/15
67		Blower Door Testing	6 days	Mon 1/12/15	Mon 1/19/15
68		Final Paint	10 days	Wed 1/14/15	Tue 1/27/15
69		Punchlist	10 days	Wed 1/28/15	Tue 2/10/15
70		**Common Space - New Building**	**89 days**	**Tue 10/21/14**	**Fri 2/20/15**
71		**Common Space MEP Rough**	**20 days**	**Tue 10/21/14**	**Mon 11/17/14**
72		Second Floor	10 days	Tue 10/21/14	Mon 11/3/14
73		First Floor	10 days	Tue 10/28/14	Mon 11/10/14
74		Ground Floor	10 days	Tue 11/4/14	Mon 11/17/14

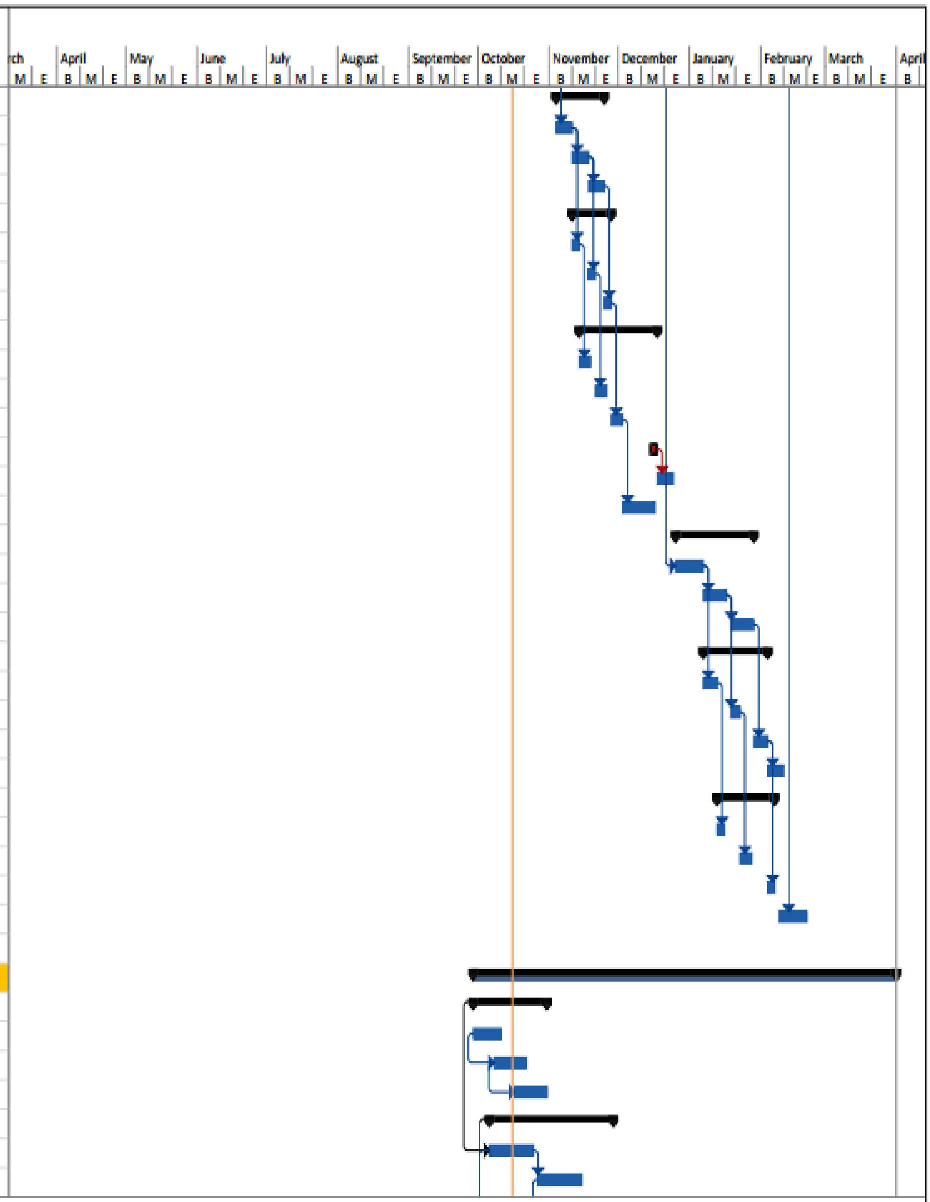


Project: Duffy Recovery Schedule

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Page 2

ID	Ta	Task Name	Duration	Start	Finish
75		**Drywall Installations - Commo**	**15 days**	**Tue 11/4/14**	**Mon 11/24/14**
76		Second Floor	5 days	Tue 11/4/14	Mon 11/10/14
77		First Floor	5 days	Tue 11/11/14	Mon 11/17/14
78		Ground Floor	5 days	Tue 11/18/14	Mon 11/24/14
79		**Common Space Trim/ Door Ins**	**13 days**	**Tue 11/11/14**	**Thu 11/27/14**
80		Second Floor	3 days	Tue 11/11/14	Thu 11/13/14
81		First Floor	3 days	Tue 11/18/14	Thu 11/20/14
82		Ground Floor	3 days	Tue 11/25/14	Thu 11/27/14
83		**Common Space Paint**	**24 days**	**Fri 11/14/14**	**Wed 12/17/14**
84		Second Floor	3 days	Fri 11/14/14	Tue 11/18/14
85		First Floor	3 days	Fri 11/21/14	Tue 11/25/14
86		Ground Floor	3 days	Fri 11/28/14	Tue 12/2/14
87		Permanant Power	3 days	Mon 12/15/1	Wed 12/17/14
88		**Elevator Rough Install**	5 days	Thu 12/18/14	Wed 12/24/14
89		HVAC Installations	10 days	Wed 12/3/14	Tue 12/16/14
90		**MPE Finish**	**24 days**	**Fri 12/26/14**	**Wed 1/28/15**
91		Second Floor	8 days	Fri 12/26/14	Tue 1/6/15
92		First Floor	8 days	Wed 1/7/15	Fri 1/16/15
93		Ground Floor	8 days	Mon 1/19/15	Wed 1/28/15
94		**Carpet/ Tile Install**	**20 days**	**Wed 1/7/15**	**Tue 2/3/15**
95		Second Floor	4 days	Wed 1/7/15	Mon 1/12/15
96		First Floor	4 days	Mon 1/19/15	Thu 1/22/15
97		Ground Floor	4 days	Thu 1/29/15	Tue 2/3/15
98		Elevator Final	5 days	Wed 2/4/15	Tue 2/10/15
99		**Final Paint**	**19 days**	**Tue 1/13/15**	**Fri 2/6/15**
100		Second Floor	3 days	Tue 1/13/15	Thu 1/15/15
101		First Floor	3 days	Fri 1/23/15	Tue 1/27/15
102		Ground Floor	3 days	Wed 2/4/15	Fri 2/6/15
103		Punchlist	10 days	Mon 2/9/15	Fri 2/20/15
104					
105		**Existing Building**	**132 days**	**Mon 9/29/14**	**Tue 3/31/15**
106		**Unit Framing**	**24 days**	**Mon 9/29/14**	**Thu 10/30/14**
107		Second Floor	10 days	Mon 9/29/14	Fri 10/10/14
108		First Floor	10 days	Wed 10/8/14	Tue 10/21/14
109		Ground Floor	10 days	Fri 10/17/14	Thu 10/30/14
110		**MPE Rough**	**40 days**	**Mon 10/6/14**	**Fri 11/28/14**
111		Second Floor	15 days	Mon 10/6/14	Fri 10/24/14
112		First Floor	15 days	Mon 10/27/1	Fri 11/14/14



Project: Duffy Recovery Schedule										
	Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
	Split		External Tasks		Inactive Summary		Manual Summary		Progress	
	Milestone		External Milestone		Manual Task		Start-only			
	Summary		Inactive Task		Duration-only		Finish-only			

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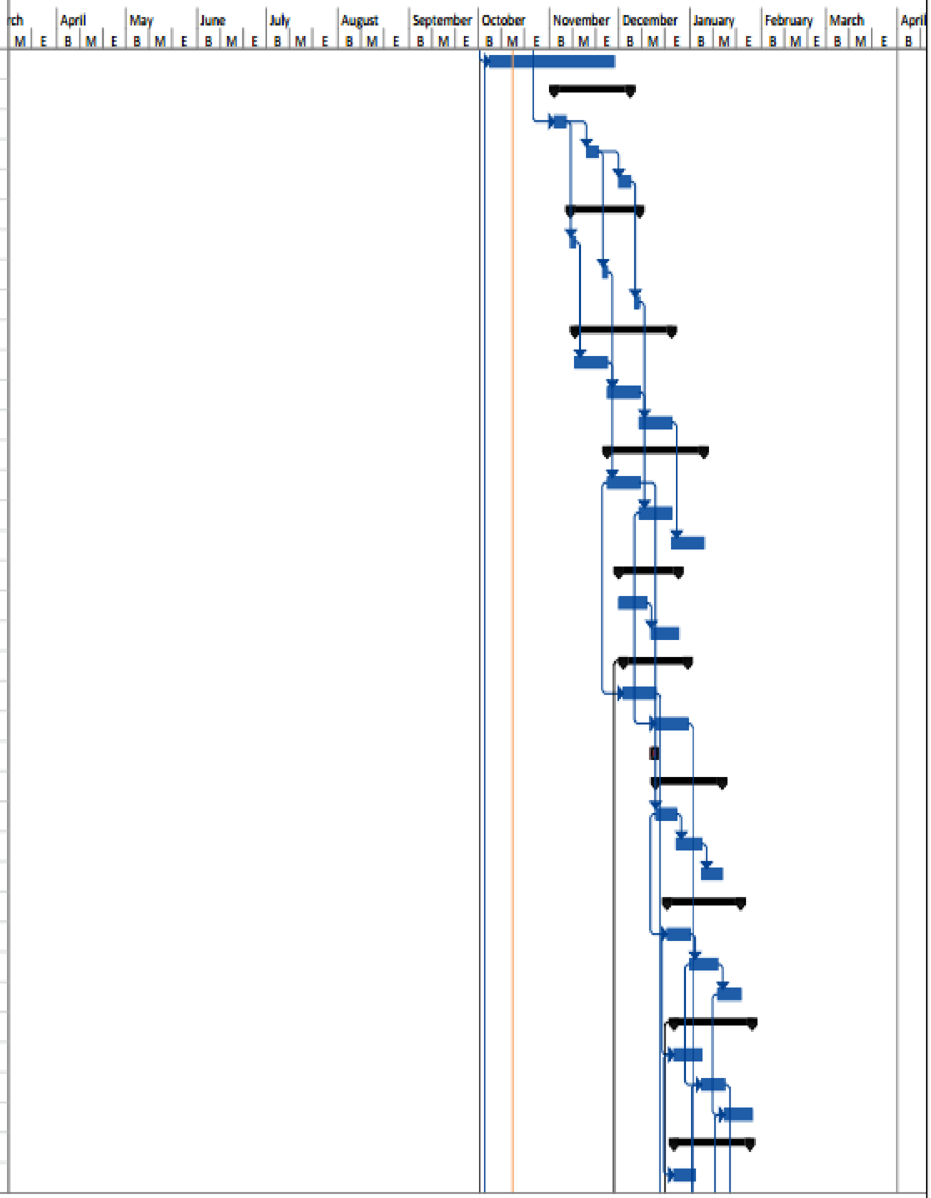
ID	Task Mode	Task Name	Duration	Start	Finish
113		Ground Floor	40 days	Mon 10/6/14	Fri 11/28/14
114		**Wall Foam Insulation**	**25 days**	**Mon 11/3/14**	**Fri 12/5/14**
115		Second Floor	5 days	Mon 11/3/14	Fri 11/7/14
116		First Floor	5 days	Mon 11/17/1	Fri 11/21/14
117		Ground Floor	5 days	Mon 12/1/14	Fri 12/5/14
118		**Energy/ Inspections**	**22 days**	**Mon 11/10/1**	**Tue 12/9/14**
119		Second Floor	2 days	Mon 11/10/1	Tue 11/11/14
120		First Floor	2 days	Mon 11/24/1	Tue 11/25/14
121		Ground Floor	2 days	Mon 12/8/14	Tue 12/9/14
122		**Drywall Installations**	**30 days**	**Wed 11/12/1**	**Tue 12/23/14**
123		Second Floor	10 days	Wed 11/12/1	Tue 11/25/14
124		First Floor	10 days	Wed 11/26/1	Tue 12/9/14
125		Ground Floor	10 days	Wed 12/10/1	Tue 12/23/14
126		**Unit Trim/ Unit Door Installation**	**30 days**	**Wed 11/26/1**	**Tue 1/6/15**
127		Second Floor	10 days	Wed 11/26/1	Tue 12/9/14
128		First Floor	10 days	Wed 12/10/1	Tue 12/23/14
129		Ground Floor	10 days	Wed 12/24/1	Tue 1/6/15
130		**Historic Window Installations**	**20 days**	**Mon 12/1/14**	**Fri 12/26/14**
131		South Elevation	10 days	Mon 12/1/14	Fri 12/12/14
132		North Elevation	10 days	Mon 12/15/1	Fri 12/26/14
133		**Historic Trim/ Tin Ceilings**	**20 days**	**Wed 12/3/14**	**Tue 12/30/14**
134		Second Floor	10 days	Wed 12/3/14	Tue 12/16/14
135		First Floor	10 days	Wed 12/17/1	Tue 12/30/14
136		Permanant Power	3 days	Mon 12/15/1	Wed 12/17/14
137		**Unit Paint**	**21 days**	**Wed 12/17/1**	**Wed 1/14/15**
138		Second Floor	7 days	Wed 12/17/1	Thu 12/25/14
139		First Floor	7 days	Fri 12/26/14	Mon 1/5/15
140		Ground Floor	7 days	Tue 1/6/15	Wed 1/14/15
141		**Hard Surface Flooring**	**24 days**	**Mon 12/22/1**	**Thu 1/22/15**
142		Second Floor	8 days	Mon 12/22/1	Wed 12/31/14
143		First Floor	8 days	Thu 1/1/15	Mon 1/12/15
144		Ground Floor	8 days	Tue 1/13/15	Thu 1/22/15
145		**Kitchen Installations**	**24 days**	**Thu 12/25/14**	**Tue 1/27/15**
146		Second Floor	8 days	Thu 12/25/14	Mon 1/5/15
147		First Floor	8 days	Tue 1/6/15	Thu 1/15/15
148		Ground Floor	8 days	Fri 1/16/15	Tue 1/27/15
149		**HVAC Heater Installations**	**23 days**	**Thu 12/25/14**	**Mon 1/26/15**
150		Second Floor	7 days	Thu 12/25/14	Fri 1/2/15

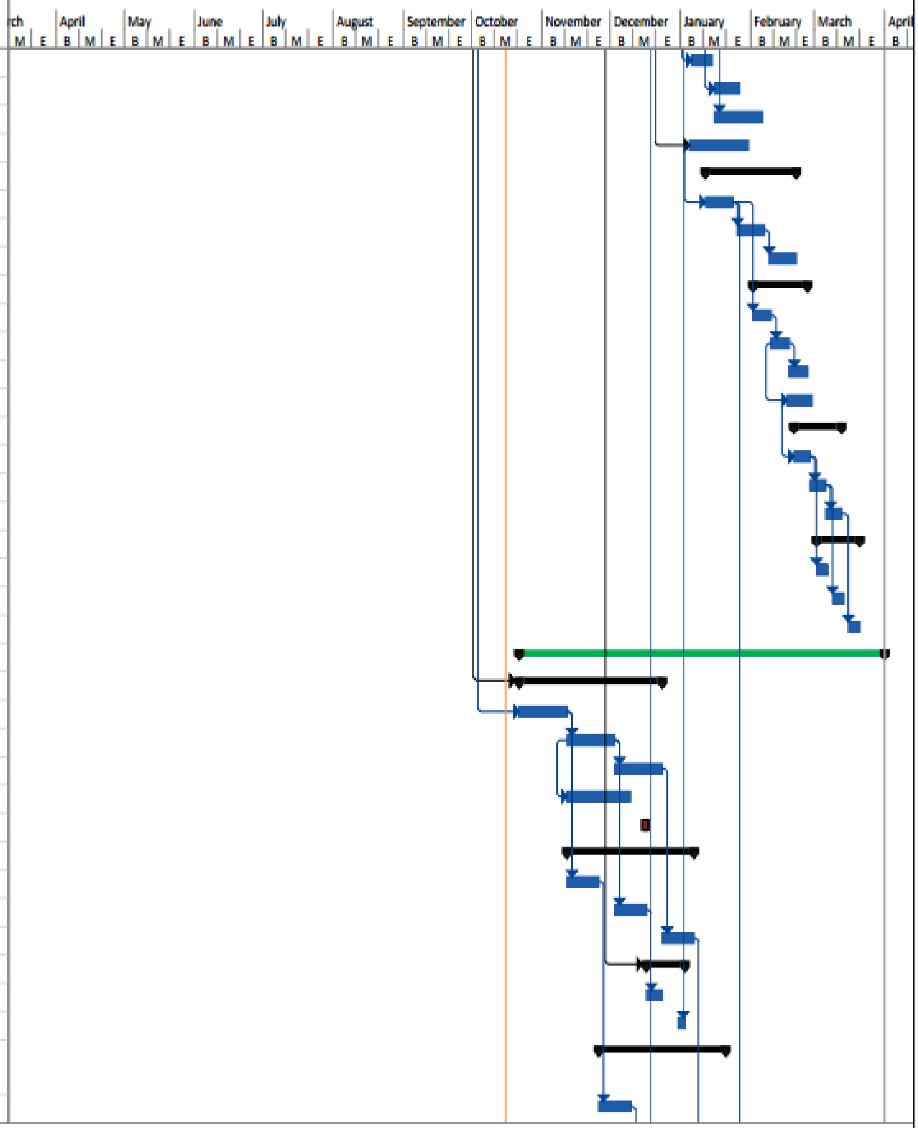


Project: Duffy Recovery Schedule

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Page 4

ID	Task Mode	Task Name	Duration	Start	Finish
151		First Floor	7 days	Tue 1/6/15	Wed 1/14/15
152		Ground Floor	7 days	Fri 1/16/15	Mon 1/26/15
153		Appliance Installations	15 days	Fri 1/16/15	Thu 2/5/15
154		Plumbing Installations	20 days	Mon 1/5/15	Fri 1/30/15
155		**MPE Finish**	**30 days**	**Mon 1/12/15**	**Fri 2/20/15**
156		Second Floor	10 days	Mon 1/12/15	Fri 1/23/15
157		First Floor	10 days	Mon 1/26/15	Fri 2/6/15
158		Ground Floor	10 days	Mon 2/9/15	Fri 2/20/15
159		**Carpet Install**	**18 days**	**Mon 2/2/15**	**Wed 2/25/15**
160		Second Floor	6 days	Mon 2/2/15	Mon 2/9/15
161		First Floor	6 days	Tue 2/10/15	Tue 2/17/15
162		Ground Floor	6 days	Wed 2/18/15	Wed 2/25/15
163		Blower Door Testing	9 days	Tue 2/17/15	Fri 2/27/15
164		**Final Paint**	**15 days**	**Fri 2/20/15**	**Thu 3/12/15**
165		Second Floor	5 days	Fri 2/20/15	Thu 2/26/15
166		First Floor	5 days	Fri 2/27/15	Thu 3/5/15
167		Ground Floor	5 days	Fri 3/6/15	Thu 3/12/15
168		**Punchlist**	**15 days**	**Mon 3/2/15**	**Fri 3/20/15**
169		Second Floor	5 days	Mon 3/2/15	Fri 3/6/15
170		First Floor	5 days	Mon 3/9/15	Fri 3/13/15
171		Ground Floor	5 days	Mon 3/16/15	Fri 3/20/15
172		**Common Space - Existing Buildin**	**115 days**	**Wed 10/22/1**	**Tue 3/31/15**
173		**Common Space MEP Rough**	**45 days**	**Wed 10/22/1**	**Tue 12/23/14**
174		Second Floor	15 days	Wed 10/22/1	Tue 11/11/14
175		First Floor	15 days	Wed 11/12/1	Tue 12/2/14
176		Ground Floor	15 days	Wed 12/3/14	Tue 12/23/14
177		Transformer/ Emergency Gene	20 days	Wed 11/12/1	Tue 12/9/14
178		Permanant Power	3 days	Mon 12/15/1	Wed 12/17/14
179		**Drywall Installations**	**40 days**	**Wed 11/12/1**	**Tue 1/6/15**
180		Second Floor	10 days	Wed 11/12/1	Tue 11/25/14
181		First Floor	10 days	Wed 12/3/14	Tue 12/16/14
182		Ground Floor	10 days	Wed 12/24/1	Tue 1/6/15
183		**Historic Trim & Tin Ceiling Inst**	**13 days**	**Wed 12/17/1**	**Fri 1/2/15**
184		Second Floor	5 days	Wed 12/17/1	Tue 12/23/14
185		First Floor	3 days	Wed 12/31/1	Fri 1/2/15
186		**Common Space Trim/ Door Installations**	**40 days**	**Wed 11/26/14**	**Tue 1/20/15**
187		Second Floor	10 days	Wed 11/26/1	Tue 12/9/14



Project: Duffy Recovery Schedule

Task	Project Summary	Inactive Milestone	Manual Summary Rollup
Split	External Tasks	Inactive Summary	Manual Summary
Milestone	External Milestone	Manual Task	Start-only
Summary	Inactive Task	Duration-only	Finish-only
Deadline	Progress		

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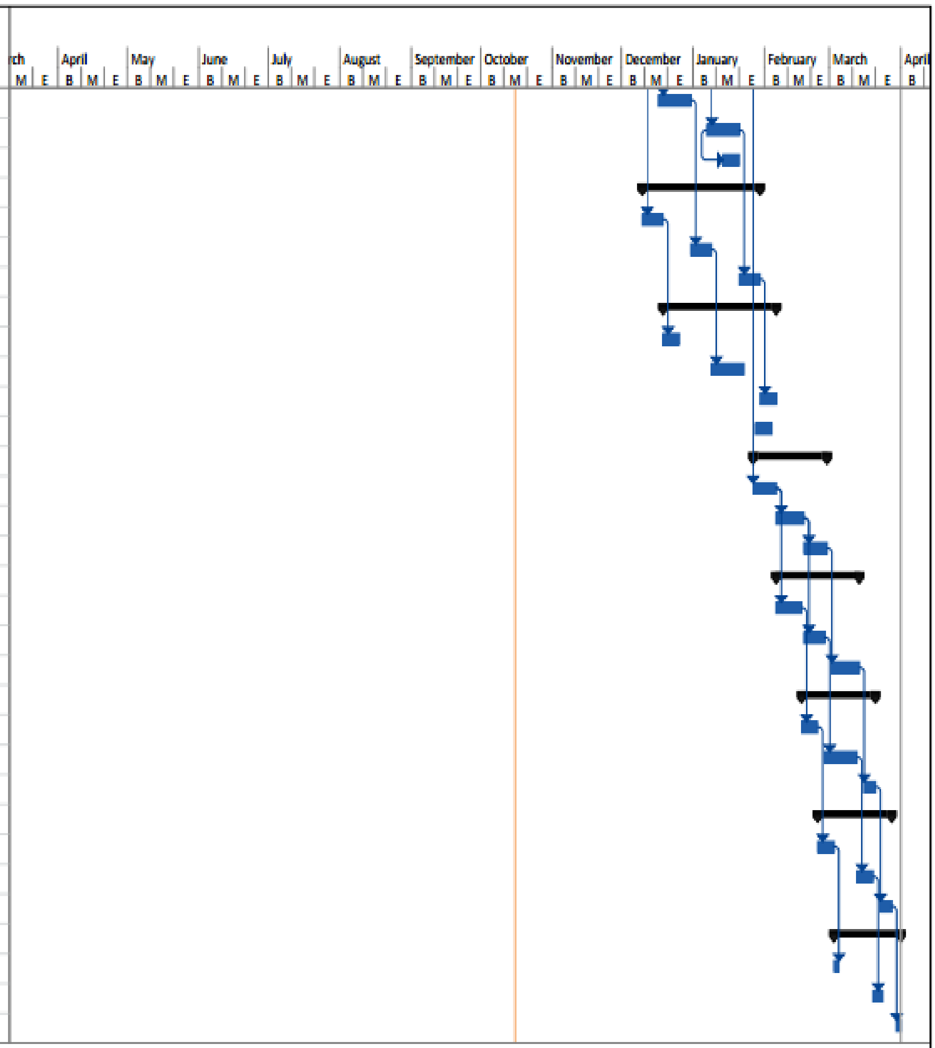
ID	Ta Mo	Task Name	Duration	Start	Finish
188		First Floor	10 days	Wed 12/17/1	Tue 12/30/14
189		Ground Floor	10 days	Wed 1/7/15	Tue 1/20/15
190		Auditorium Glazing Replaceme	5 days	Wed 1/14/15	Tue 1/20/15
191		**Plaster Installations**	**37 days**	**Wed 12/10/1**	**Thu 1/29/15**
192		Second Floor	7 days	Wed 12/10/1	Thu 12/18/14
193		First Floor	7 days	Wed 12/31/1	Thu 1/8/15
194		Ground Floor	7 days	Wed 1/21/15	Thu 1/29/15
195		**Common Space Paint**	**35 days**	**Fri 12/19/14**	**Thu 2/5/15**
196		Second Floor	5 days	Fri 12/19/14	Thu 12/25/14
197		First Floor	10 days	Fri 1/9/15	Thu 1/22/15
198		Ground Floor	5 days	Fri 1/30/15	Thu 2/5/15
199		Trash Chute Installation	5 days	Wed 1/28/15	Tue 2/3/15
200		**MPE Finish**	**24 days**	**Tue 1/27/15**	**Fri 2/27/15**
201		Second Floor	8 days	Tue 1/27/15	Thu 2/5/15
202		First Floor	8 days	Fri 2/6/15	Tue 2/17/15
203		Ground Floor	8 days	Wed 2/18/15	Fri 2/27/15
204		**Carpet/ Tile Install**	**26 days**	**Fri 2/6/15**	**Fri 3/13/15**
205		Second Floor	7 days	Fri 2/6/15	Mon 2/16/15
206		First Floor	7 days	Wed 2/18/15	Thu 2/26/15
207		Ground Floor	10 days	Mon 3/2/15	Fri 3/13/15
208		**Final Paint**	**24 days**	**Tue 2/17/15**	**Fri 3/20/15**
209		Second Floor	5 days	Tue 2/17/15	Mon 2/23/15
210		First Floor	10 days	Fri 2/27/15	Thu 3/12/15
211		Ground Floor	5 days	Mon 3/16/15	Fri 3/20/15
212		**Punchlist**	**24 days**	**Tue 2/24/15**	**Fri 3/27/15**
213		Second Floor	5 days	Tue 2/24/15	Mon 3/2/15
214		First Floor	5 days	Fri 3/13/15	Thu 3/19/15
215		Ground Floor	5 days	Mon 3/23/15	Fri 3/27/15
216		**Final Inspections**	**21 days**	**Tue 3/3/15**	**Tue 3/31/15**
217		Second Floor	2 days	Tue 3/3/15	Wed 3/4/15
218		First Floor	2 days	Fri 3/20/15	Mon 3/23/15
219		Ground Floor	2 days	Mon 3/30/15	Tue 3/31/15



Project: Duffy Recovery Schedule

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

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Appendix B: Existing Site Conditions


ADJACENT PROPERTIES
ALLEY
SUMMER ST
SPRING ST
TRASH
EXIT
RESTROOMS
EXISTING BUILDING
ADDITION
MATERIAL
CRANE
OFFICE
ENTER
SECOND STREET

Appendix C: General Conditions Estimate

PROJECT: *The Duffy School*

CODE	Work Description	Cost Per Unit	Quantity	UOM	Total Estimate
Supervision/Project Management					
01.21.00	Project Manager Labor	$2,415.00	26	Wk	$62,790.00
01.21.00	1-Project Laborer	$993.00	52	Wk	$51,636.00
01.21.00	1-Project Laborer	$993.00	26	Wk	$25,818.00
01.21.00	Superintendent Labor	$1,250.00	52	Wk	$65,000.00
01.21.00	Asst. Superintendent Labor	$880.00	52	Wk	$45,760.00
01.21.00	Administration Clerical Labor	$425.00	52	Wk	$22,100.00
	Subtotal				**$273,104.00**
Field Engineering					
01.32.23	Survey	$850	1	EA	$850.00
01.43.39	Mockups	$800.00	1	LS	$800.00
01.45.23	Testing & Allowances (Soils)	$1,200	12	LS	$14,400
01.45.29	Concrete Testing (per test per Bldg.)	$402.00	4	LS	$1,608.00
	Subtotal				**$17,658.00**
Administrative					
01.32.33	Photographic Documentation	$25.00	12	MO	$300.00
01.51.13	Trailer Electric service install	$965.00	1	LS	$965.00
01.51.13	Trailer Electric Monthly Cost	$550.00	12	MO	$6,600.00
01.51.13	Temp. Power Installation (per bldg.)	$200.00	2	LS	$400.00
01.51.13	Temp. Power Usage (per bldg.)	$300.00	12	MO	$3,600.00
01.51.23	Temp. Heat - Equipment (4 high hats)	$120.00	2	Bldg.	$480.00
01.51.29	Temporary Heat Fuel	$3,575.00	2	Bldg.	$7,150.00
01.51.33	Trailer Telephone Monthly Costs	$400.00	12	MO	$4,800.00
01.51.36	Drinking Water & cups	$50.00	12	MO	$600.00
01.51.36	Temp. Water Installation	$600.00	1	LS	$600.00
01.51.36	Temp. Water Usage	$30.00	12	MO	$360.00
01.52.13	Site Trailer Set up & Tear down	$780.00	1	LS	$780.00
01.52.13	Trailer Field Office Rental	$500.00	12	MO	$6,000.00
01.52.13	Storage Containers/Trailers (per container)	$250.00	12	MO	$3,000.00
01.52.19	Temp. Toilets (cost per based upon 5 toilets)	$500.00	12	MO	$6,000.00
01.54.19	Rental Equipment Fork lift	$3,600.00	6	EA	$21,600.00
01.56.26	Temporary Fencing (6mo-1yr rental w/RR)	$4.50	1,600	LF	$7,200.00
01.58.13	Temp. Project Signage	$1,000.00	1	LS	$1,000.00
	Subtotal				**$71,435.00**
Safety					
01.51.16	Fire Protection (fire extinguishers)	$65.00	8	EA	$520.00
01.52.16	First Aid/ Safety Supplies	$150.00	1	LS	$150.00

	Subtotal				**$670.00**
Cleanup					
01.74.13	Final Clean Buildings	$0.35	61,115	SF	$21,390.25
01.74.19	Dumpsters	$600.00	61,115	SF	$36,669.00
	Subtotal				**$58,059.25**
Miscellaneous					
01.78.53	Drawing Reproduction	$0.07	61,115	SF	$4,339.17
	Subtotal				**$4,339.17**
	General Requirements Total				**$425,265.42**

Appendix D: LEED Scorecard

LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name: The Duffy School

Date: 10/17/2014

Y	?	N		Location and Transportation	32
6	5	21			
		16	Credit	LEED for Neighborhood Development Location	16
		1	Credit	Sensitive Land Protection	1
		2	Credit	High Priority Site	2
	5		Credit	Surrounding Density and Diverse Uses	5
5			Credit	Access to Quality Transit	5
		1	Credit	Bicycle Facilities	1
1			Credit	Reduced Parking Footprint	1
		1	Credit	Green Vehicles	1

Y	?	N		Sustainable Sites	10
8	2	0			
Y			Prereq	Construction Activity Pollution Prevention	Required
1			Credit	Site Assessment	1
2			Credit	Site Development - Protect or Restore Habitat	2
1			Credit	Open Space	1
3			Credit	Rainwater Management	3
	2		Credit	Heat Island Reduction	2
1			Credit	Light Pollution Reduction	1

Y	?	N		Water Efficiency	11
3	8	0			
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
2			Credit	Outdoor Water Use Reduction	2
	6		Credit	Indoor Water Use Reduction	6
	2		Credit	Cooling Tower Water Use	2
1			Credit	Water Metering	1

Y	?	N		Energy and Atmosphere	33
30	3	0			
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
6			Credit	Enhanced Commissioning	6
18			Credit	Optimize Energy Performance	18
	1		Credit	Advanced Energy Metering	1
	2		Credit	Demand Response	2
3			Credit	Renewable Energy Production	3
1			Credit	Enhanced Refrigerant Management	1
2			Credit	Green Power and Carbon Offsets	2

Y	?	N		Materials and Resources	13
8	0	5			
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
		5	Credit	Building Life-Cycle Impact Reduction	5
2			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
2			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
2			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
2			Credit	Construction and Demolition Waste Management	2

Y	?	N		Indoor Environmental Quality	16
11	2	3			
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
2			Credit	Enhanced Indoor Air Quality Strategies	2
3			Credit	Low-Emitting Materials	3
		1	Credit	Construction Indoor Air Quality Management Plan	1
		2	Credit	Indoor Air Quality Assessment	2
1			Credit	Thermal Comfort	1
2			Credit	Interior Lighting	2
3			Credit	Daylight	3
	1		Credit	Quality Views	1
	1		Credit	Acoustic Performance	1

Y	?	N		Innovation	6
0	6	0			
	5		Credit	Innovation	5
	1		Credit	LEED Accredited Professional	1

Y	?	N		Regional Priority	4
0	4	0			
	?		Credit	Regional Priority: Specific Credit	1
	?		Credit	Regional Priority: Specific Credit	1
	?		Credit	Regional Priority: Specific Credit	1
	?		Credit	Regional Priority: Specific Credit	1

Y	?	N	TOTALS	Possible Points:	125
58	25	29			

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110