The Educational Activities Building

Penn State Harrisburg | Middletown, PA

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Analysis 1: Green Roof System
Analysis 2: MEP Systems Prefabrication
Analysis 3: Structural Steel Sequencing
Analysis 4: Technology Integration for Information Management

Structural Breadth

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General Contractor

Reynolds

Architect

BCJ Architecture

Owner	Penn State University
Location	Middletown, PA
Occupant Type	Business Group B
Size	55,057 GSF
Height	2 Stories and a Penthouse/ 48’
Project Cost	$19.4 Million
Construction Dates	Feb 2013- May 2014
Delivery Method	Design-Bid-Build
Contract Type	GMP

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Presentation Outline:

Mechanical System:

- Central station air handling unit
- Variable air flow distribution system
- Chilled water for cooling and hot water for heating

Central station air handling unit

Electrical System:

- 40kW emergency generator
- Majority of lighting is LED

LED Lighting Fixtures

Architecture:

- Curtain walls & aluminum panels.
- L-shaped building with a penthouse
- Designed to be LEED certified
- Connected to existing building by a pedestrian walkway connector

Structural System:

- Structural steel frame, mostly different sizes of wide flanges steel beam sand columns
- Cast-in-Place Concrete for footings, foundation walls and slab-on-grade

Building Exterior

Building Structural Frame

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Problem Statement

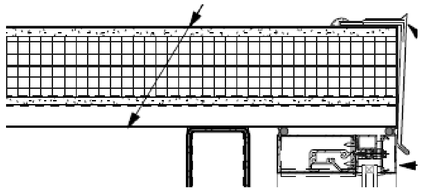
There is a potential to increase e the building value and performance with the addition of a green roof system.

Roof System:

- 1 ½“ Metal Deck
- ½“ Exterior Gypsum Sheathing
- Air/Vapor Barrier
- 4” Rigid Insulation
- ½“ Gypsum Cover Board
- Single Ply Membrane

Extensive Green Roof:

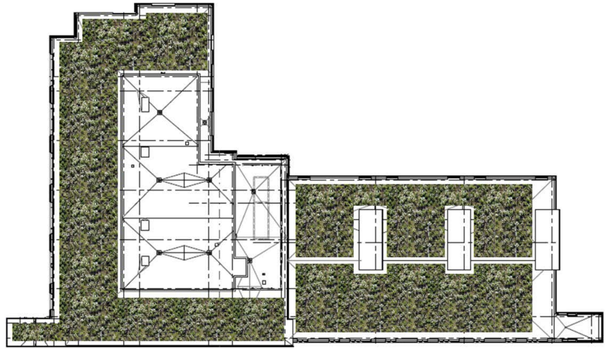
- 3-5 inches deep
- 15-25 lbs/ft²
- Low maintenance
- No irrigation required
- Ideal for PV/Solar System integration



Roof System Sectional View

Extensive Green Roof System

The Proposed Design



16,000 SF of Extensive Green Roof which covers about 60% of the total roof area

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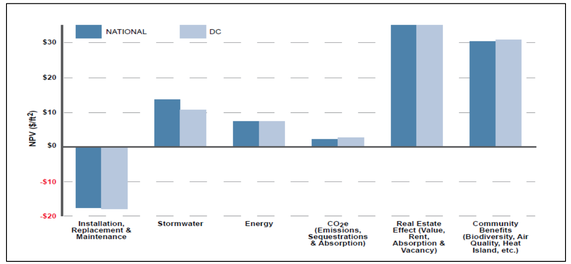
Constructability Review:

- The roof will be built as designed
- Pre-grown extensive vegetation trays delivery
- Man power is used to place the trays

Pre-grown Extensive Vegetation Trays

Description	Quantity	Daily Output (SF)	Total Material Cost ($)	Total Labor Cost ($)	Total Cost ($)
4“ Green Roof System	16,000	4,000	168,000	13,120	181,120

Green Roof Cost Estimation



Cost Benefit Analysis

Loading (PSF)	Level 2 Roof and Penthouse Level Roof
Concrete Slab	40
Metal Deck	2
Additional ¾” Concrete	8
M/E/C/L	8
Membrane	4
Insulation	5
Beam/Grinder Self-Weight	5
Green Roof Weight	25
Total Dead Load	**97**
Live Load (ASCE Table 4-1)	100
Total Load	**197**

Dead and Live Loads

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Structural Analysis Equations

Live Load Reduction

$$L = L_o\left[.25 + \frac{15}{\sqrt{K_{LL}A_t}}\right]$$

Factored Distributed Load

$$W=(1.2)(D_L)+(1.6)(L)$$

Factored Bending Moment

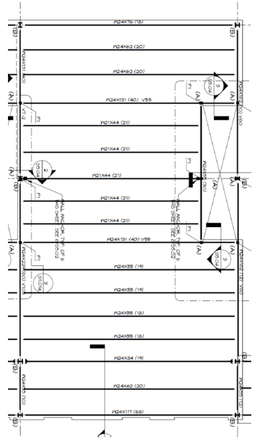
$$M_u = \frac{(w_u)(l^2)}{8}$$

Factored Shear

$$V_u = \frac{(w_u)(l)}{2}$$

Beams 5” spacing 0.C.	Grinders
38.5’ W21x44	
44.5’ W24x55	11’ W24x55
44.5’ W24x62	31.5’ W24x131
44.5’ W24x76	31.5’ W24x162
44.5’ W24x84	37.5’ W24x162
44.5’ W24x117	37.5’ W24x229
44.5’ W24x131	

Beams and Grinders



Typical Building Bay

Type	Moment (k-ft)	Max. Moment (k-ft)	Shear (Kips)	Max. Shear (Kips)	Result
Beams					
W21x44	256.06	**358**	25.99	**217**	Passing
W24x55	334.17	**503**	30.04	**252**	Passing
W24x62	334.17	**574**	30.04	**306**	Passing
W24x76	334.17	**750**	30.04	**315**	Passing
W24x84	334.17	**840**	30.04	**340**	Passing
W24x117	334.17	**1230**	30.04	**400**	Passing
W24x131	334.17	**1390**	30.04	**444**	Passing
Grinder					
W24x55	40.53	**503**	14.74	**252**	Passing
W24x131	441.55	**1390**	56.07	**444**	Passing
W24x162 (31.5 ft)	441.55	**1760**	56.07	**529**	Passing
W24x162 (37.5 ft)	722.46	**1760**	77.06	**529**	Passing
W24x229	722.46	**2530**	77.06	**749**	Passing

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Cons
- High Initial Cost, $181,120
- 4 Days Installation Process

Pros
- Energy Savings
- Increased Property Value
- Noise Reduction
- Better Stormwater Control
- Extend Roof Membrane Lifespan

Recommendation
Due to the initial high cost and low ROI, implementing this solution is not recommended.

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Problem Statement

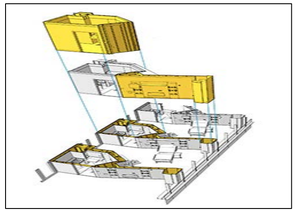
The MEP systems activities overlap each other , which causes congestion on the construction site.

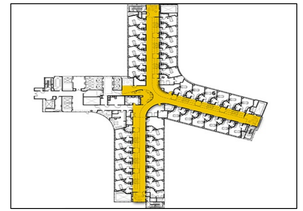
Task	Start Date	Finish Date	Duration (Days)
Mechanical System	7/17/2013	12/26/2013	117
Electrical System	9/4/2013	12/24/2013	80
Plumbing System	9/4/2013	1/9/2014	92

Original MEP Systems Schedule

Case Study: Miami Valley Hospital Addition

- 178 Headwalls and Bathroom Pods.
- 120 Integrated MEP Corridor Racks
- Productivity tripled
- 20% less Labor Cost
- Reduced schedule by 2 months
- Saved 1-2% of the project overall cost





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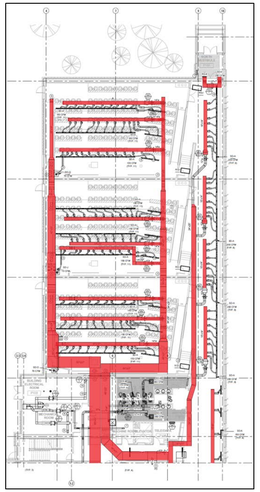
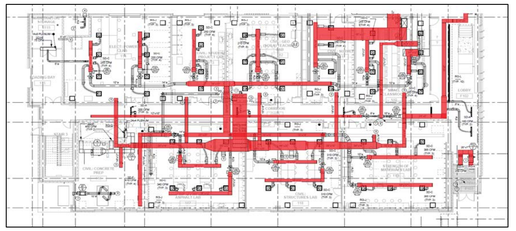
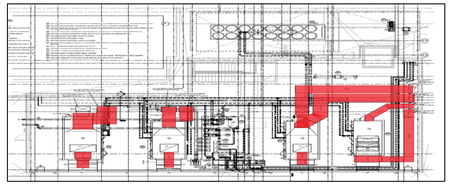
Mechanical System Scope

Only main Ductwork branches are considered for Prefabrication, sizes range from 12"x10" to 84"x24"





The main Ductwork branches that are considered for Prefabrication



Electrical System Scope

- Copper Conduit with a ½" diameter or more
- Cast Iron Pipes with 3" and 4" diameters

Plumbing System Scope

- Copper Pipes type L with diameters between ½" and 2 ½"
- Cast Iron Pipes with 4" & 6" diameters
- Black Steel Pipes with a 2" diameter

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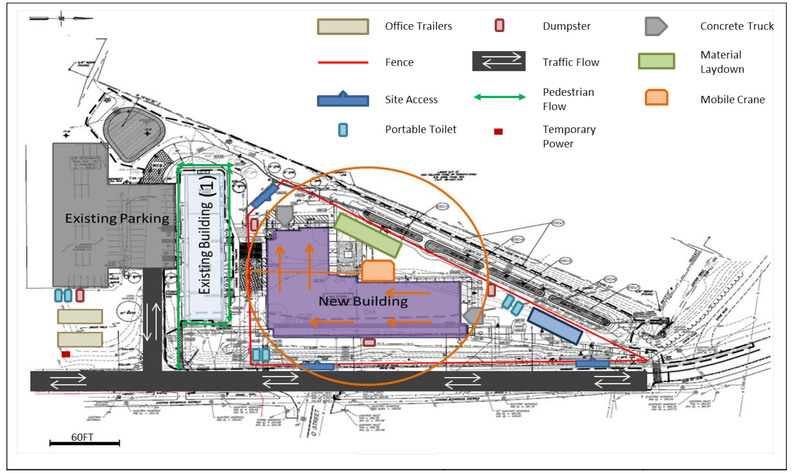
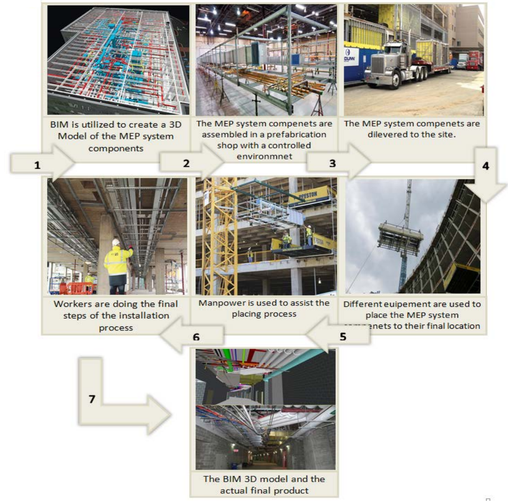
Construction Site Layout

- Two Gates
- Low Height
- Material Laydown area
- Mobile Crane



The Construction Site Layout



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- Prefabrication productivity is double on-site productivity

Contractor	Original Installation Duration (Days)	Prefabrication Installation Duration (Days)	Duration Reduction (Days)
Mechanical	117	64	53
Electrical	80	45	35
Plumbing	92	51	41
Total	127	86	**41**

Days Reduced for each Contractor and the Overall Project Schedule

Task	Start Date	Finish Date	Duration (Days)
Mechanical System	7/17/2013	10/14/2013	64
Electrical System	9/4/2013	11/5/2013	45
Plumbing System	9/4/2013	11/13/2013	51

New MEP Systems Schedule

	Onsite Labor Cost ($)	Prefabrication Labor Cost ($)	Total Labor Cost Savings ($)
Mechanical	237,931.2	68,546.56	169,384.64
Electrical	126,796.8	38,340	88,456.80
Plumbing	148,686.72	44,198.64	104,488.08
Crane Operator	-10,272.2	-	-10,272.2
Crane	-23,220	-	-23,220
Total	479,922.52	151,085.20	**328,837.32**

Labor Cost Savings for each Contractor

General Conditions	Original Duration (Days)	Duration Reduction (Days)	Cost per Day ($/Day)	Total General Conditions Cost Savings ($)
	127	41	3,176.54	**130,238.14**

General Conditions Cost Savings

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Cons
- Requires Early Coordination between the MEP Systems Teams
- Using Cranes for Additional Days

Pros
- Less Site Congestion
- Schedule Reduced by **41 Days**
- **$328,837.32** Labor Cost Savings
- **$130,238.14** General Conditions Savings

Recommendation

Due to the cost savings of **$459075.46** and **41 Days** schedule Reduction, the implementation of the solution is recommended.

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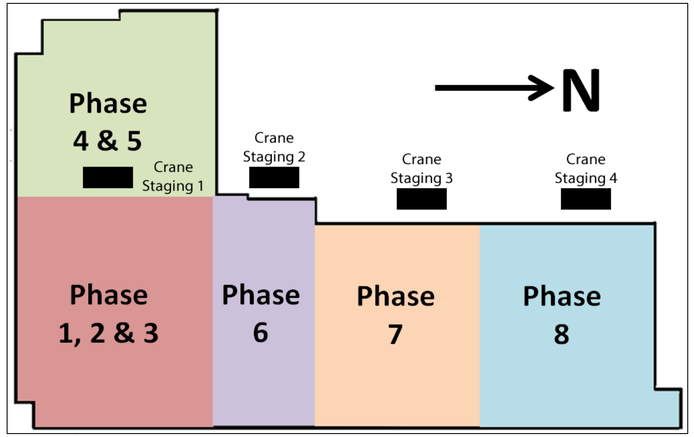
Problem Statement

The structural steel erection is a critical path item, but there is a potential to improve the sequence and accelerate the schedule.



The Current Steel Sequence and Crane Staging

General Site Information

- 94,050 SF. construction site
- First Street is the only main road adjacent to the Site
- An exciting building is located South of the project
- Material laydown area is located West of the North Wing

Steel Sequence Planning Considerations

- Crane Type and Size
- Crane Locations
- Material Laydown Area
- Steel Deliveries

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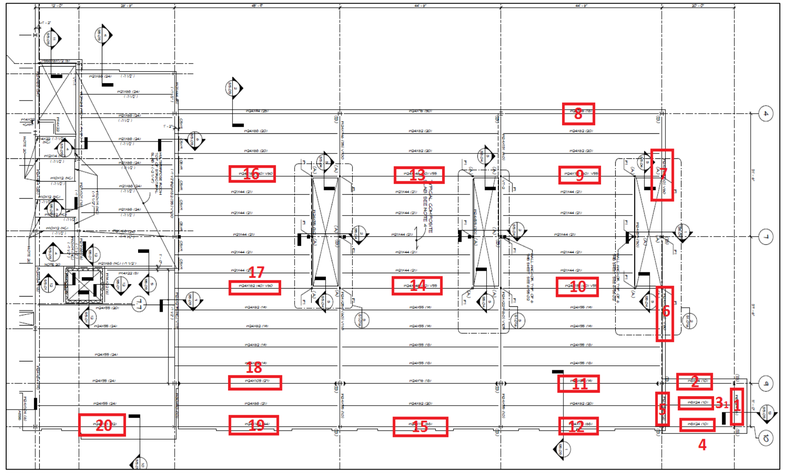
Crane Selected

- Rough Terrain Hydraulic Crane
- 50 Ton Capacity
- 110 Boom

Hydraulic Crane



The Critical Beams Location of the North Wing

Beam #	Beam Size	Beam Length (ft)	Beam Weight (lb)	Distance from Crane	Safety Check
Beam 1	W8x24	11	264	90	Passes
Beam 2, 3 & 4	W8x24	20	480	90	Passes
Beam 5	W24x55	11	605	85	Passes
Beam 6	W24x162	37.5	6,075	80	Passes
Beam 7	W24x162	44.5	5,103	75	Passes
Beam 8	W24x76	44..5	3,382	60	Passes
Beam 9 & 10	W24x131	44.5	5,829.5	65-75	Passes
Beam 11	W24x84	44.5	3,783	80	Passes
Beam 12	W24x117	44.5	5,206	85	Passes
Beam 13 & 14	W24x146	44.5	6,497	30-40	Passes
Beam 15	W24x117	44.5	5,206	60	Passes
Beam 16, 17 & 19	W24x162	45.75	7,411	30-60	Passes
Beam 18	W24x103	45.75	4,712	50	Passes
Beam 20	W24x131	38.5	5,043	70	Passes

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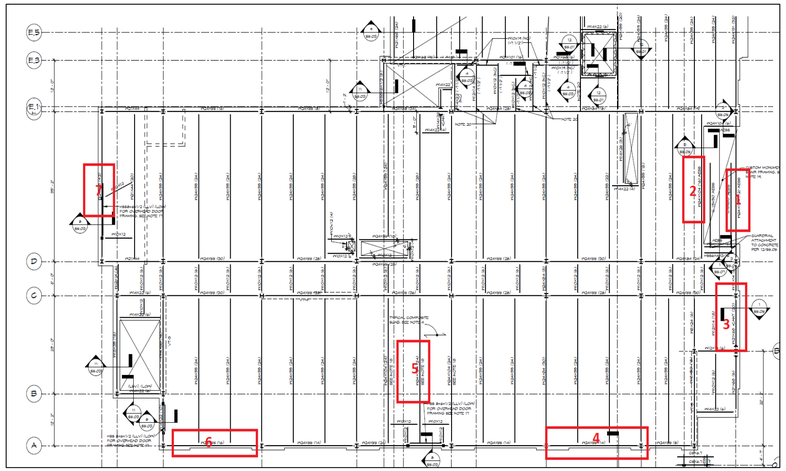
Presentation Outline:



The Critical Beams Location of the South Wing

Beam #	Beam Size	Beam Length (ft)	Beam Weight (lb)	Distance from Crane	Safety Check
Beam 1	W24x104	35.17	3,657	75	Passes
Beam 2	W24x104	35.17	3,657	70	Passes
Beam 3	W21x68	22.17	1,507	85	Passes
Beam 4	W24x55	25	1,375	90	Passes
Beam 5	W24x104	35.17	3,657	75	Passes
Beam 6	W24x55	26’	1,730	85	Passes
Beam 7	W24x68	35.17	2,391	75	Passes

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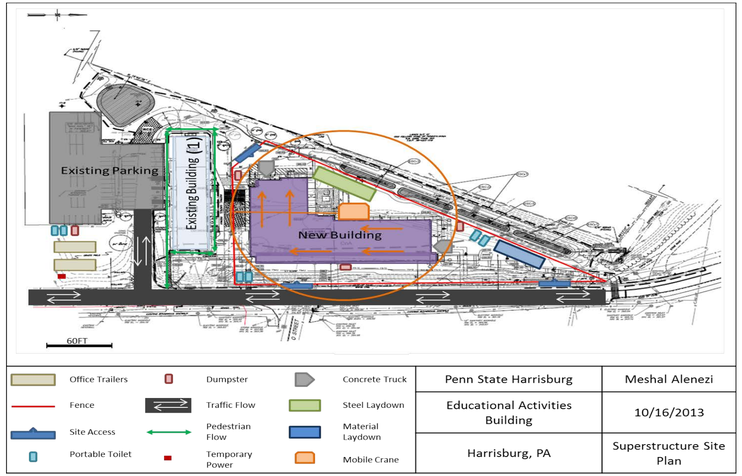

The Proposed Site Plan and Crane Location

Criteria	Original Steel Sequence	Proposed Steel Sequence
Crane Size	30 Ton, 90’ Boom, 43’ Jib	50 Ton, 110’ Boom, 32’ Jib
# of Crane Locations	4	1
Duration (Days)	26	18
Steel Deliveries Phases	4	3
Steel Laydown	Within 30’ from the crane	Within 30’ from the crane
Sequence Direction	S Wing to the N Wing	N Wing to the S Wing

Comparison Between the Original and Proposed Steel Sequence

	Daily Cost ($/Day)	Schedule Reduction (Days)	Total Savings ($)
Structural Labor	239.5	8	1,916
Crane/Crane Operator	389.4	8	3115.2
General Conditions	3,176.54	8	25,412.32
Total			30,527.52

The Cost Savings & Schedule Reduction

Cons
- Bigger and More Expensive Crane

Pros
- Schedule Reduced by **8 Days**
- **$5,031.2** Labor Cost Savings
- **$25,412.32** General Conditions Savings

Recommendation
Due to the cost savings of **$30,527.52** and **8 Days** schedule Reduction, the implementation of the solution is recommended.

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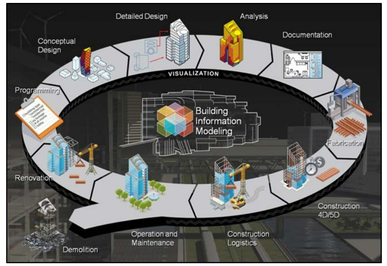
Opportunity Identification

22nd annual PACE Roundtable introduced the use of technology for Information Management.



BIM Uses

Technology Implemented on the Project

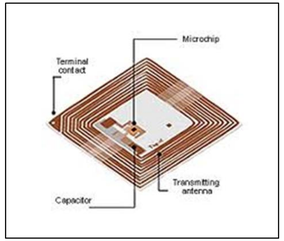
❖ BIM Uses
- Different Project Phases: Planning, Design, Construction and Turnover.
- Coordination & Modeling
- Clash Detection
- Asset Management

❖ Electronic Documents

"Proper use of technology will also reduce change orders and cost of construction." Mr. Adam Dent, Project Manager.

Technology Tools Used in the Construction Industry

Tablets are becoming popular tools to view project documents and exchange information on site.



RFID Tags are used to keep track of materials.

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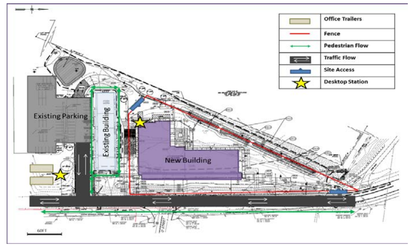

Site Plan and Desktop Station Locations

- Two Desktop Stations
- 18 FieldLens Memberships
- 6 Tablets
- BIM
  - "Document Management"
  - "Building Maintenance Scheduling"

Item	Quantity	Cost $/Unit	Total Cost $
Generic Tablets	6	4,00	2,400
FieldLens Membership	18	20 (per month for 16 months)	5,760
Desktops	2	6,00	1,200
Desktop Stations	2	65	130
Utility Cost			104
Total			**10,594**

The Cost of Implementation

Item	Quantity (Hours per week)	Cost ($) /Unit (Hour)	Total Cost Savings ($) Per Week
Penn state Project Manager	5	95	475
Penn state BIM Manager	5	65	325
Reynolds Construction BIM Manager	5	65	325
Reynolds Construction Project Executive	5	103	515
Reynolds Construction Project Manager	5	95	475
Reynolds Construction On-Site Construction Manager	5	90	450
IT Technician	5	70	-350
Total			**2,215**

The Cost Savings

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Pros

- Improved Communication and Documents Sharing
- **$2,215/Week** General Conditions Savings

Recommendation

Due to the cost savings of **$141,760** over the entire project duration, the implementation of the solution is recommended.

The Educational Activities Building

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Analysis1: Green Roof System:

- High Initial Cost, $181,120
- 4 Days Installation Process

Recommendation

Due to the initial high cost and low ROI, implementing this solution is not recommended.

Analysis2: MEP Systems Prefabrication

- Less Site Congestion
- Schedule Reduced by **41 Days**
- **$328,837.32** Labor Cost Savings
- **$130,238.14** General Conditions Savings

Recommendation

Due to the cost savings of **$459075.46** and **41 Days** schedule Reduction, the implementation of the solution is recommended.

Analysis3: Structural Steel Sequencing

- Schedule Reduced by **8 Days**
- **$5,031.2** Labor Cost Savings
- **$25,412.32** General Conditions Savings

Recommendation

Due to the cost savings of **$30,527.52** and **8 Days** schedule Reduction, the implementation of the solution is recommended.

Analysis4: Technology Integration for Information Management:

- Improved Communication and Documents Sharing
- **$2,215/Week** General Conditions Savings

Recommendation

Due to the cost savings of **$141,760** over the entire project duration, the implementation of the solution is recommended.

Academic
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Dr. Moses Ling
Dr. Kevin Parfitt
Dr. John Messner

Special Thanks
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Mr. Tim Sullivan
Ms. Natalie Gentile
Mr. Brian Shaffer
PACE Industry Members

Industry
Reynolds Construction
BCJ Architecture
Penn State OPP

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