Presentation Outline

• Project Background
• ANALYSIS#1: Multi-Trade Prefabrication Study
• ANALYSIS#2: Cost Estimating Through 3D Modeling
• ANALYSIS#3: Feasibility of Solar PV-System
  • Electrical Breadth
  • Structural Breadth (Will Not Be Discussed)
• Lessons Learned
• Acknowledgements
Presentation Outline:
I. Project Background
II. Analysis #1: Multi-Trade Prefabrication
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   • Analysis of Survey
   • Guidelines For Implementation
IV. Analysis #3: Solar PV-Panels
   • Solar Analysis
   • Manufacturers
   • Electrical Production Calculations
   • Financial Analysis
V. Lessons Learned
VI. Acknowledgements

Project Background

Building Name: Children's Hospital
Location: 500 University Drive, Hershey, PA 17033
Gross Building Area: 262,587 SF
Number of Stories: 5-Stories + Underground Level
Delivery Method: Design-Bid-Build w/ CM Agency @ Risk

Contracted GMP Amount: $115 Million
Construction Dates: March 17th, 2010 – August 20th, 2012
LEED Certification: Certified

Courtesy of Payette Associates
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Project Background

PROJECT TEAM

Owner: Penn State Milton S. Hershey Medical Center
Architect: Payette Associates
Construction Manager: L.F. Driscoll Co, LLC
Structural Engineer: Gannett Fleming INC
MEP Engineer: BR+A Consulting Engineers, LLC
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Project Background

Structural System:
- Column Piers + Grade Beams on Micropiles
- Structural Steel Framing
- Elevated Slabs on Metal Decks

Building Façade:
- CMU Back-Up
- Limestone and Granite Cladding with Metal Panels
- Curtain Wall with LED Fitted Mullions

Construction Phases:
- Site-Grade Preparation
- Superstructure Erection
- Structural Skin Erection
- Building Water-Tight and Fitouts
- Site Improvements
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Multi-Trade Prefabrication

Problem Identification
- Site Congestions
- Limited Material Laydown Areas
- Reduced Productivity

Research Goal
- Determine Systems That Could be Prefabricated
- Reduce Schedule
- Cost Implications
Presentation Outline:

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Multi-Trade Prefabrication

WHAT TO PREFABRICATE?

Total Amount of Prefabricated Units:

<table>
<thead>
<tr>
<th>Unit</th>
<th>3rd Floor</th>
<th>4th Floor</th>
<th>Total</th>
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<td>34</td>
<td>68</td>
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<td>HEADWALL</td>
<td>21</td>
<td>21</td>
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<tr>
<td>FOOTWALL</td>
<td>17</td>
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Multi-Trade Prefabrication

Schedule Impact

250 SF of Wall Per Day Using RS MEANS Productivity Data

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<th>UNIT</th>
<th>QUANTITY</th>
<th>SF OF WALL PER UNIT</th>
<th>TOTAL SF</th>
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<td>6120 SF</td>
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<td>4 DAYS</td>
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<td>SUB TOTAL</td>
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<td></td>
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<td>SUB TOTAL</td>
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<td>29 DAYS</td>
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<td>TOTAL</td>
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<td>22020 SF</td>
<td>58 DAYS</td>
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</table>

29 DAYS SAVED PER FLOOR FITOUT!

General Conditions Impact

GC Calculated to be $6.62 Millions over 31 Months
58 Days of Project Schedule Saving = $427,131 of GC Savings
Multi-Trade Prefabrication

Where to Prefabricate the Systems?
- 20,000 SF Warehouse in Harrisburg, PA
- 11 Miles from jobsite
- Rental Rate = $5.25/SF Per Month
- 2 Months of Rental
- Total Cost of $105,000

Truck Loads Required
- Bathroom Pods = 2 Per Truck  TOTAL 34 Deliveries
- Headwalls = 2 Per Truck  TOTAL 21 Deliveries
- Footwalls = 4 Per Truck  TOTAL 9 Deliveries
- Total Miles 1408 @ $3.20 per mile = $4,500 For Deliveries

Site Logistics

Where to Prefabricate the Systems?
- 20,000 SF Warehouse in Harrisburg, PA
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- Total Miles 1408 @ $3.20 per mile = $4,500 For Deliveries
Multi-Trade Prefabrication

Final Conclusion
- 58 Days of Schedule Reduction
- $427K Worth of GC Savings
- Major Reduction in site congestions

Recommendation
- Pursue Prefabrication of Patient Rooms
- Met goals of reducing schedule and site congestions
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3D ESTIMATING

Problem Identification

- Excessive Time to Quantify Materials
- Less Time for Constructability Reviews
- Less Time for Planning

Research Goal

- Accuracy of Building Models for Estimation
- Time Savings in Software Based QTO.
- Develop a Guideline for Implementing 3D Estimating

Quantity Take-Offs Using Revit
Methodology Used

- Traditional Quantity Take-offs
- Revit Quantity Take-offs
- Determine Time Savings and Accuracy of Each Method
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3D ESTIMATING

ANALYSIS OF SURVEY
Based on 25 Completed Surveys

When Do You See Greatest Advantage in 3D Estimating?

<table>
<thead>
<tr>
<th>Phase</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>VE/Addendums/ Bulletins</td>
<td>30%</td>
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<tr>
<td>Schematic Phase</td>
<td>10%</td>
</tr>
<tr>
<td>Design Development Phase</td>
<td>50%</td>
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</table>

Can 3D Estimating Eliminate the Traditional Manual Methods?

- Yes: 11%
- No: 89%

3D ESTIMATING ANALYSIS OF SURVEY

Based on 25 Completed Surveys

When Do You See Greatest Advantage in 3D Estimating?

- VE/Addendums/ Bulletins: 30%
- Schematic Phase: 10%
- Design Development Phase: 50%

COMMENTS MADE

- Waste of Time
- Models Not Created the way Building is Built
- Better Visualization
- The Older People Not Been Exposed to 3D Estimating
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3D ESTIMATING

Guide Lines For Implementing 3D Estimating Methods

- BIM only Aids in Estimation and is not a Total Solution
- Initially Attempt utilizing Digital Take-Offs
- Test Accuracy of BIM Quantity Take-Offs
- Do Not Attempt Linking Models with Other Softwares

Final Conclusion

- Less Time Counting Building Materials
- Allows More Time for Critical Planning
- Ease in Updating Estimates
- Increase Competitive Advantage
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PHOTOVOLTAIC SYSTEM

Problem Identification
- Borderline of LEED Silver Certification
- Few Sustainable Systems Incorporated
- Great Potential for Sustainable Systems

Research Goal
- Eliminate a Diesel Generator
- Determine Feasibility of a PV System

Photo Credit: Courtesy of Google Images
Photovoltaic System

Solar Analysis

Building Location  Hershey, Pa
Elevation at Roof  85 Ft
Latitude and Longitude  N 40°15'/ W 76°46'
Sun Hours Per Day for Building  (4.44)

Optimum System Orientation  South Facing Side
Optimum System Tilt Angles  Summer: 25° 15'
                          Winter: 55°
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Electric Demand
• Annually 7,221,143 kWh
• Monthly 601,762 kWh
• Daily 19,784 kWh

More Realistic Approach (Electric Breadth)
• 4200 SF Roof Space
• 240 Panels

Manufacturers and Panels Needed
• Kyocera (KD235GX-LP) 18961 Panels
• BP Solar (BP3230T) 19373 Panels
• Suntech (STP210-18) 21218 Panels

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Panel Requirements Per End Use
<table>
<thead>
<tr>
<th>End Use</th>
<th>Watt Hours Per Day</th>
<th># of Panels Req’d</th>
<th>Is it Feasible?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office Equip.</td>
<td>1 MWH</td>
<td>197840</td>
<td>18961</td>
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<td>Space Heating</td>
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<tr>
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<td>Ventilation</td>
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<tr>
<td>Others</td>
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<td>197840</td>
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<tr>
<td>TOTAL</td>
<td>100 MWH</td>
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PHOTOVOLTAIC SYSTEM

Electric Energy Production

(System Layout)

Summary of Calculations

- Adequate AC Energy for Office Equipment
- 72969 kWh Produced • Only 72211 kWh Needed
- Savings of $6800 Annually on Electric Bill
- Covers 1% of Total Electric Demand
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PHOTOVOLTAIC SYSTEM

Cost of System

- @ $7500 / KW-DC (U.S. Department of Energy Figure)
- Designed System 56.4 kW-DC

Incentives

- PA Sunshine PV Rebate (com. > 10-100 kW) = $25,000
- PA Sunshine PV Rebate (com. > 3-10 kW) = $7,500
- Federal PV Tax Credit = $135,000

Total System Cost

- $423,000 System Cost
- Federal Incentives Totaling $154,307
- Final System Cost Less Incentives $268,693

PHOTOVOLTAIC SYSTEM

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PHOTOVOLTAIC SYSTEM

Assumptions Made

- Owner will pay Costs Up-Front
- Cost of Electricity = $0.093/KWh
- Annual Escalation % = 1.5%
- Value of SREC= $250 per 1000 KWh

Payback Period

- Payback in Just 11 Years
- System Warranted for 25 Years
- Generate Money After 11th Year

<table>
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<tr>
<th>Year</th>
<th>Cost of Solar Panel $</th>
<th>Cost of SREC $</th>
<th>Total Cost $</th>
<th>Total SREC $</th>
<th>Cash Flow $</th>
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</table>
PHOTOVOLTAIC SYSTEM

Final Conclusion
- Diesel Generator Cannot be Eliminated
- 1% Electric Demand Sustainably Generated
- $6,800 Direct Electric Bill Savings Annually
- $18,000 Worth of SRECs Annually
- Payback in just 11 Years

Recommendation
- Owner Should Consider Incorporating Solar PV- Panels
- Incentives may not be Available in the Future
Presentation Outline:

I. Project Background
II. Analysis #1: Multi-Trade Prefabrication
   • What to Prefabricate?
   • Schedule and GC Impact
   • Logistics
III. Analysis #2: 3D Estimating
   • Methodologies Used
   • Analysis of Survey
   • Guidelines for Implementation
IV. Analysis #3: Solar PV-Panel
   • Solar Analysis
   • Manufacturers
   • Electrical Production Calculations
   • Financial Analysis
V. Lessons Learned
VI. Acknowledgements

LESSONS LEARNED

Analysis #1: Multi-Trade Prefabrication
• The Benefits Out Number the Risks and Increased Costs

Analysis #2: 3D Estimating
• 3D Estimating Saves Critical Time BUT IS NOT a Total Solution!
• Will not Fully Work Till Models are Modeled As-Built

Analysis #3: Photovoltaic System
• High Incentives Makes it a No Brainer to Invest in Photovoltaic
Presentation Outline:
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ACKNOWLEDGEMENTS

Pennsylvania State University – AE Department

Pennsylvania State University – Office of Physical Plant

L.F. Driscoll Co, LLC

Payette Associates

The Ministry of Higher Education of The State of Kuwait

Family

Friends

AE Classmates

Family

Friends

AE Classmates
APPENDIX

PRESENTATION OUTLINE:
I. Project Background
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ELECTRIC DEMAND CALCULATION

<table>
<thead>
<tr>
<th></th>
<th>Kyocera KD235GX-1P</th>
<th>BP Solar BP 3230T</th>
<th>Suntech STP210-18</th>
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<tbody>
<tr>
<td>Sun Hours Per Day</td>
<td>4.44</td>
<td>4.44</td>
<td>4.44</td>
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<tr>
<td>Watt Hours Per Day</td>
<td>4455856</td>
<td>4455856</td>
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<tr>
<td>Watts Per Hour of Sunlight</td>
<td>4455856</td>
<td>4455856</td>
<td>4455856</td>
</tr>
<tr>
<td>Rate of Power Per Panel</td>
<td>235W</td>
<td>280W</td>
<td>210W</td>
</tr>
<tr>
<td># of Panels Required</td>
<td>19061</td>
<td>19373</td>
<td>21218</td>
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</tbody>
</table>

NUMBER OF PANEL REQUIRED PER SYSTEM

APPENDIX

Annually

\[
\text{Electric Demand} = \frac{27.5 \text{ kW}}{\text{yr}} \times 262,587 \text{ Sq. Ft} = 7,221,143 \frac{\text{kWh}}{\text{yr}}
\]

Monthly

\[
\text{Electric Demand} = 7,221,143 \frac{\text{kWh}}{\text{yr}} \times \frac{1 \text{ year}}{12 \text{ months}} = 601,761 \frac{\text{kWh}}{\text{month}}
\]

Daily

\[
\text{Electric Demand} = 7,221,143 \frac{\text{kWh}}{\text{yr}} \times \frac{1 \text{ year}}{365 \text{ days}} = 19,784 \frac{\text{kWh}}{\text{day}}
\]
### The structural calculations were performed as outlined below:

- **Determine the weight of the PV-Panels based on the layout used**
- **Determine roof assembly weight**
- **Calculate load combinations**
- **Determine ultimate moment, **\( M_u \)**
- **Calculate required cross-section \( Z_{req'd} \) and compare with AISC values to ensure safe range**
- **Calculate maximum deflection and compare with AISC values to ensure safe range**

#### Summary of Structural Calculations

<table>
<thead>
<tr>
<th>Element</th>
<th>Max Shear, ( V_{nx} )</th>
<th>Min Shear, ( V_{ux} )</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam/16X36</td>
<td>21.959 kips</td>
<td>140 kips</td>
<td>Within Range</td>
</tr>
<tr>
<td>Girder/16X36</td>
<td>21.96 kips</td>
<td>140 kips</td>
<td>Within Range</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Max Moment, ( M_{px} )</th>
<th>Min Moment, ( M_{ux} )</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam/16X36</td>
<td>189.399 k-ft</td>
<td>240 k-ft</td>
<td>Within Range</td>
</tr>
<tr>
<td>Girder/16X36</td>
<td>175.68 k-ft</td>
<td>240 k-ft</td>
<td>Within Range</td>
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</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Max Cross Section, ( Z_{x} )</th>
<th>Min Cross Section, ( Z_{x} )</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam/16X36</td>
<td>33.675 in³</td>
<td>64 in³</td>
<td>Within Range</td>
</tr>
<tr>
<td>Girder/16X36</td>
<td>46.857 in³</td>
<td>64 in³</td>
<td>Within Range</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>Max Deflection, ( \Delta_{max} )</th>
<th>Min Deflection, ( \Delta_{max} )</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam/16X36</td>
<td>0.006705 in²</td>
<td>0.4 in²</td>
<td>Within Range</td>
</tr>
<tr>
<td>Girder/16X36</td>
<td>0.5298 in²</td>
<td>1.725 in²</td>
<td>Within Range</td>
</tr>
</tbody>
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