Images Courtesy of The Preston Partnership

SOLAIRE WHEATON

Image Courtesy of Clark Builders Group

Kevin Martyn

Final Report

Construction Option

Adviser : Dr. Rob Leicht

4/9/2014

SOLAIRE WHEATON

BUILDING FACTS

Location: Wheaton, MD
Function/Type: Multi-family residential
Size: 361,000 SF
Stories: 6 above & 2 semi-below grade
Delivery Method: CM @ Risk
Construction Dates: 6/25/12 - 3/21/14

PROJECT TEAM

Owner: Washington Property Company
Architect: The Preston Partnership
Interior Design Architect: SR/A
CM: Clark Builders Group
Civil Engineer: MHG
Structural Engineer: Cates Structural Engineers. Ltd.
MEP Engineer: Summit Engineers Inc.

STRUCTURE

- Cast-in-place concrete (3 Floors)
- Post tensioned concrete deck (3rd Floor)
- Wood framing & pre-engineered floor trusses (5 Floors)
- Tongue and groove OSB sub-floor sheathing & gypcrete

ELECTRICAL

- 208/120V electrical distribution
- 250 KW emergency generator
- (2) 4000A Switchboards

MECHANICAL

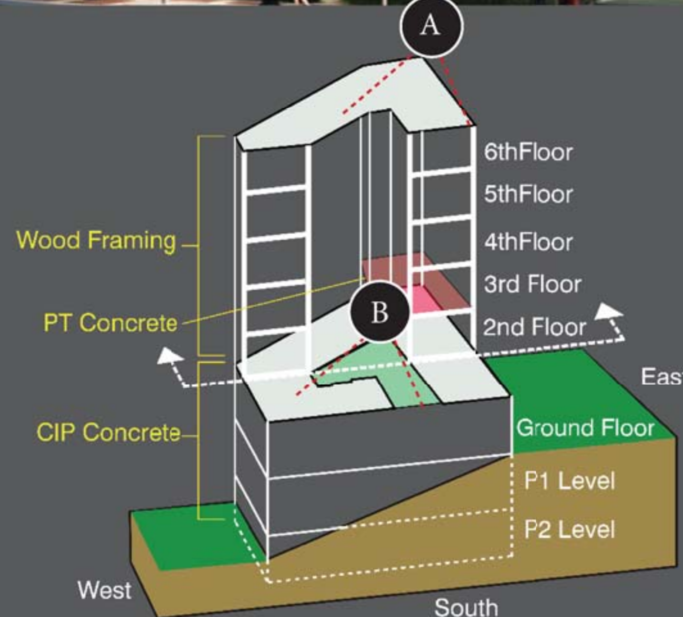
- (2) Packaged roof top central station AHU's: service corridors & common areas
- Heat pump split systems: service units & amenity areas
- Ductless split system units & circulation fans: service garage

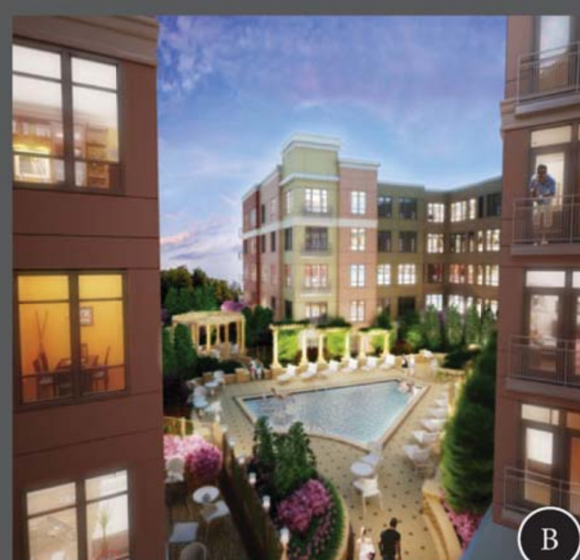
ARCHITECTURE

- Landscaped courtyard
- Swimming pool
- Fitness center
- Motor court entrance

BUILDING ENCLOSURE

- East & partial north elevations: Stone & brick
- Remaining elevations & courtyard: Fiber cement siding
- Roofing: White TPO membrane





KEVIN MARTYN [CONSTRUCTION OPTION]
http://www.engr.psu.edu/ae/thesis/portfolios/2014/kam5775/index.html

WASHINGTON PROPERTY COMPANY
Development Management Leasing

CLARK
BUILDERS GROUP

EXECUTIVE SUMMARY

The senior thesis final report documents the research and conclusions of four analyses of the construction of the Solaire Wheaton project. Solaire Wheaton is a newly constructed luxury apartment building in Wheaton, MD. The project has a 21 month construction schedule and a $31.5 million guaranteed maximum price contract. The analyses presented in this report examine the time extension implications of a self-written owner and contractor agreement, new approaches to safety orientation, and schedule reduction methods of modularization and short interval production scheduling.

Analysis 1: Contract Weather Clause

The first analysis examines the weather clause of the self-written contract used on the project as well as popular form contracts. The clause was the subject of much confusion as it was fairly uninterpretable. The Solaire Wheaton project is recommended to use predetermined anticipated weather days and daily NOAA data as the basis of it's weather clause. Using this method, the contractor should potentially be granted nine days of time extension.

Analysis 2: BIM for Safety Orientation

This analysis examines ways to use building information modeling as a tool for the site specific safety orientation of workers. The language barrier, low level of education of workers, and the ineffective use of visuals have been identified as the major issues with current safety orientation methods. Hazard identification, hospital directions, and emergency egress plans are a few of the safety items that can be displayed visually to break down these barriers to effective communication of safety information. The building information modeling tool can be used to create orientation packets of site specific safety orientation information, better preparing the workforce for the projects hazards and emergency procedures.

Analysis 3: Modularization

By shifting work off-site through modularization of the wood structure, the simultaneous sequencing allows for a potential 30-50% reduction in schedule. In order to maximize potential savings, standardization and fast-tracked design would be incorporated. With the potential modularization implementation on the Solaire Wheaton project, the overall project duration can be reduced by 2 months with an estimated cost savings of $175,000. To maximize schedule savings it was concluded that the interior finishes and building enclosure should potentially be added to the scope of the module as well.

Analysis 4: SIPs for Interior Finishes

The second phase of the project, which involves interior finishes on floors three through six, could not be accurately predicted and managed using the critical path scheduling method, resulting in a four week schedule increase. The implementation of short interval production scheduling on this phase can create a predictable and manageable smooth workflow with consistent crew sizes. The SIPs implementation resulted in a five week reduction in actual schedule and a one week reduction of the planned duration. This reduction in actual duration translates to an estimated general conditions savings of $118,563.

Schedule Acceleration Conclusion

Using modularization and SIPs schedule acceleration methods, the substantial completion date is reduced by nine weeks with a total estimated cost savings of over $294,000.

TABLE OF CONTENTS

ACKNOWLEDGMENTS

Academic:

Dr. Rob Leicht - Construction Adviser

Jerry Pisarcik - Contract Adviser

Kevin Parfitt

Industry:

CLARK BUILDERS GROUP

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PROJECT BACKGROUND

Solaire Wheaton is a 361,000 square foot luxury apartment building in the upcoming city of Wheaton, MD. The project consists of a 108,000 square foot semi-below grade two-story parking garage topped by six floors of apartments, totaling 232 units. The design consists of a podium structure with a cast-in-place concrete ground floor topped by five stories of wood framing. Podium structures are becoming increasingly popular allowing owners to build less expensively using wood framing, resulting in a quicker return on investment. The luxury apartment units come in twenty-one different layouts and have a modern style to them as illustrated in Figure 1.1.

In 2010 the owner of the project, Washington Property Company (WPC), began steps to develop the plot of land by demolishing the existing church, to make room for the new apartment building. WPC is seeking to take advantage of the opportunity in a booming area by offering affordable housing. The area of Wheaton is just north of Silver Spring, MD, approximately 10 miles from Washington, D.C. Located only two miles from the Georgia Avenue exit of the outer loop of the beltway, this site is a prime location for commuting professionals.

Figure 1.1. Interior Rendering Courtesy of Solaire

Schedule is the most important factor to the success of the project as several other apartment buildings are being constructed in the area. The team's goal is to complete the project first and lock in pursuing tenants.

As seen in Figure 1.2, in order to make this possible, the owner required a phased occupancy plan with the first turnover in November 2013, seventeen months after the start of construction. The first turnover includes the garage and site, first floor, courtyard, and amenity spaces located on the 1st and 2nd floors. This enables the marketing team to show apartments and sign leases prior to substantial completion. Substantial completion is scheduled for March 21st, 2014, for a total of twenty one months of construction.

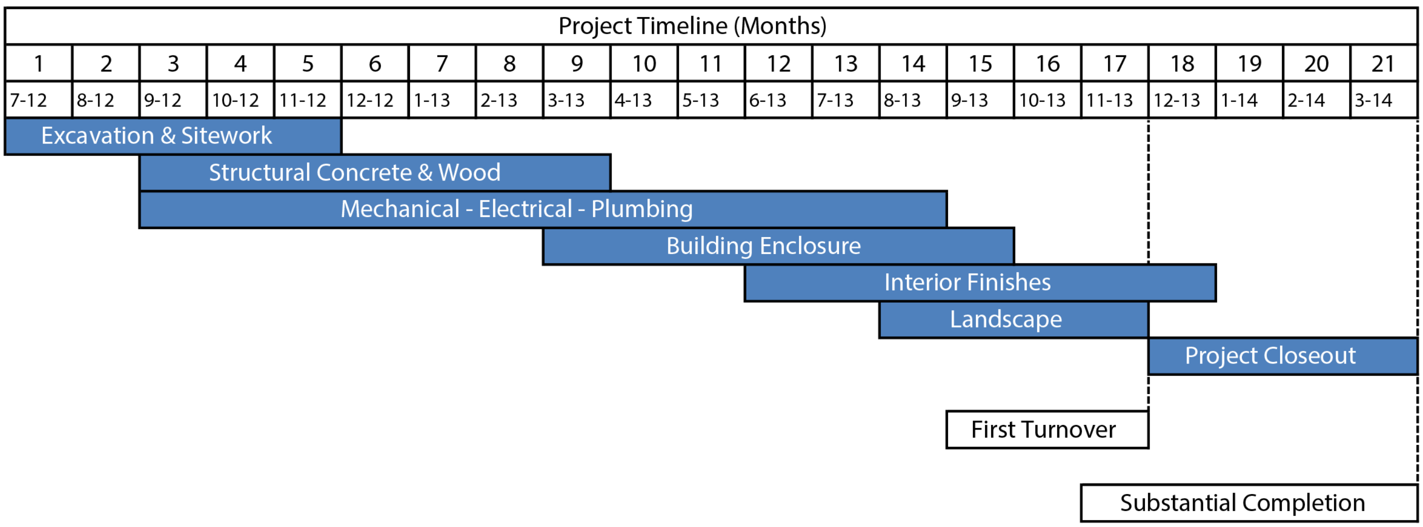


Figure 1.2. Project Summary Schedule

SITE AND GENERAL BACKGROUND

ARCHITECTURE

Solaire Wheaton is an apartment building which sits on the site of a previously existing church. The structure consists of 209 market rate units and 29 moderately priced dwelling units (MPDU) units. Individual apartments come in a variety of layouts for studio, single bedroom, and double bedroom units. The building hosts a wide range of amenities including a landscaped courtyard on the second floor seen in Figure 1.3 at the right, as well as a swimming pool, a wifi café, clubroom, a fitness center, and a motor court entrance below the courtyard off of Georgia Avenue.

Figure 1.3. Courtyard Rendering

EXCAVATION & EARTH RETENTION

The site required some excavation to accommodate the two story semi-below grade parking garage. Site access was located at the southeast corner of the site where trucks entered to take soils off site. As seen in Figure 1.4 to the right, the site could utilize sloped excavation on the east elevation towards Georgia Avenue. The geotechnical engineer recommended a small earth retention system of soldier beams and wood lagging in the northeast corner of the site also seen in the bottom part of Figure 1.4.

Figure 1.4. Excavation & Earth Retention

STRUCTURAL SYSTEM

As seen in, Figure 1.5 to the right, the Solaire Wheaton design uses several structural systems including cast in place concrete, post tensioned concrete, and wood framing. This type of podium structure is becoming increasingly popular in the Washington D.C. metro area allowing for cheaper and faster constructed buildings.

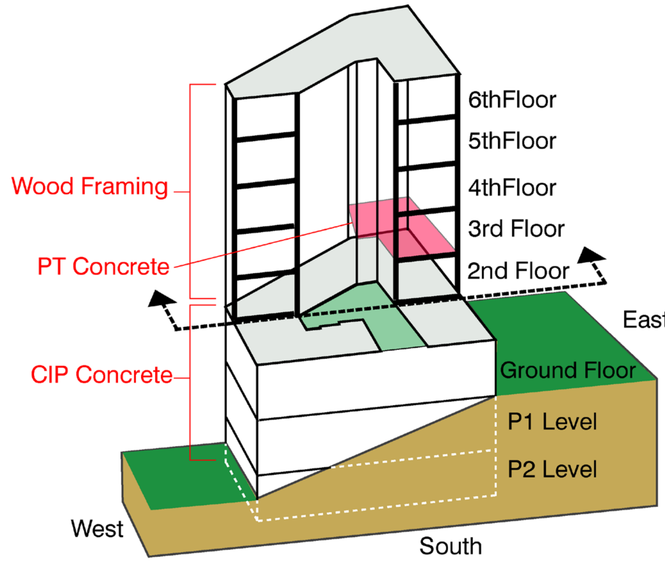


Figure 1.5. Structural 3D Section

The foundation of the structure consists of column spread footings as well as foundation wall strip footings. The foundation walls are located on the east elevation along Georgia Avenue and the site slopes gradually to grade at level P2 on the west elevation.

Garage levels P1 and P2 as well as the first floor are constructed of cast in place concrete. P2, the lowest level, consists of a 5" thick slab on grade placed with 3500 psi concrete. P1 is an 8" thick typical elevated slab with drop panels and a 10" thick garage ramp slab down to P2. The ground floor and 2nd floor are also cast in place concrete with an 8" thick concrete slab. The 2nd floor involves a courtyard with a swimming pool. Typical column size for this area of the building is 14" x 24" with 10' x 10' column drop panels.


Figure 1.6. Structural Post Tensioned Deck

As seen in Figure 1.6 to the left, the northeast corner of the third floor of this structure utilizes a 10 ½" thick post tensioned concrete podium transfer slab. The PT tendons are laid out with a maximum spacing of 60", with an assumed effective strength of the tendons after all losses of 27 kips.

The remaining structure from the 2nd floor to the 6th is constructed of wood framing. The walls are framed at 12" on center. The floors are designed as 18" deep pre-engineered open web wood trusses typically spaced at 24" on center. Shear is resisted by exterior wall sheathing and shear panels secured to one side of the trusses along the corridors.

MECHANICAL SYSTEM

The mechanical system for the building is separated into two separate systems. The common spaces on floors 1 through 6 are conditioned by two 50 ton packaged rooftop air handling units supplying 7500 cubic feet per minute (CFM). The air handling units (AHU's) use direct expansion cooling and natural gas heating. They are located on the east and west sides of the building and air is supplied through shafts that descend through the building along the corridors. The apartment units and amenity spaces are conditioned by split system heat pumps. Residential units are serviced by 600 and 800 CFM heat pumps respectively based on their heating and cooling load. Condensing units are located on the roof while the air handling units are hung on the wall in the units mechanical closet. In order to meet the Indoor Air Quality Management requirements for section 01450 of LEED, all ducts were protected during construction.

ELECTRICAL SYSTEM

Solaire Wheaton uses a three phase 208/120 V electrical distribution system provided by PEPCO. Service is stepped down by two transformers located on the southeast corner of the building, adjacent to the garage entrance. The secondary distribution wires are then fed to the main electrical room located on the southeast corner on the P1 level. The main electric room houses the two switchboards, rated at 4000A each. Switchboard 1 feeds the meter stack closets located on floors 4 and 6. The meter stack closets are located in pairs on every other floor in the southwest and northeast corners of the building. Switchboard 2 feeds the meter stack closets on floor 2 as well as the emergency power service.

Emergency power is supplied by a 250 KW diesel engine generator. Each apartment unit has its own panel which are rated at 125 amps for single bedroom units and 150 amps for the two bedroom units.

BUILDING ENCLOSURE

As seen in Figure 1.7 to the right, the façade of the building is comprised of masonry stone and brickwork on the east and partial north elevations to give an impressive look from Georgia Avenue paired with James Hardie fiber cement board siding on the remaining elevations and within the courtyard. These exterior finishes are secured through the tyvek vapor retarder and fire rated wood sheathing. The openings of the building are filled with aluminum windows and doors manufactured by Thermal Windows. In order to accommodate for the excessive traffic noise on Georgia Avenue, the windows on the east and north elevations were manufactured with a higher STC rating.

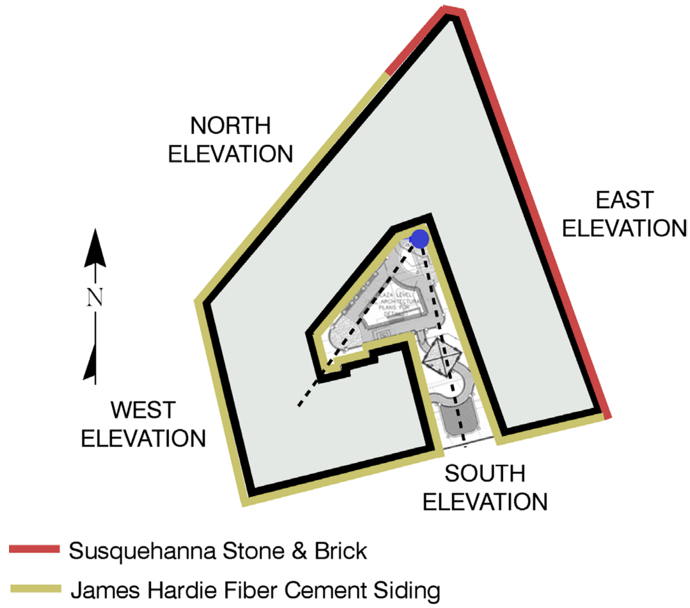


Figure 1.7. Exterior Enclosure

Figure 1.8. TPO Membrane Roof

The building is capped with a flat roof system that uses a combination of interior and exterior water drainage systems. As photographed at the left in Figure 1.8, the building's roof is closed in with a thermoplastic polyolefin membrane (TPO) roof and metal coping on the parapet and canopy walls.

CONSTRUCTION STUDY 1 – CONTRACT WEATHER CLAUSE

PROBLEM IDENTIFICATION

The Solaire Wheaton project utilizes a self-written owner and contractor agreement as a pose to a form contract such as AIA or Consensus Docs. Although this allows the parties to adjust the clause to fit the needs of the project, the problem associated with this type of agreement is that both parties can be unfamiliar with self-written clauses, creating ambiguity in the contract language. With an aggressive schedule on the project, each excessive weather day can cause extensive delays. The summer of 2013 in the Wheaton, MD area was particularly rainy and coincided with exterior enclosure activities on the project. Window installation was halted during the poor weather, and the soils typically took at least one additional day to dry out before exterior work could resume. Work was being performed from boom lifts, causing work to be halted for days at a time, as the lifts would get stuck in the mud. The project team was looking into the weather delay clause to determine whether or not they had legal justification to recover days in the schedule. The self-written clause was not easily interpreted and required significant analysis to determine if rain days were recoverable.

As engineers, we always try to explain things with an equation. Without a metric system of determining results, consistent interpretation is very difficult. This seems to be the issue with the self-written weather clause. Effective contract clauses should be able to be interpreted by two separate people and produce the same result.

BACKGROUND RESEARCH

Construction delays can be separated into two categories for contractual reasons: excusable and non-excusable delays. Non-excusable delays are foreseeable or within the contractor's control, and therefore are not excused by the owner. In this case, the contractor is not entitled to an extension of time nor delay damages that may have resulted.

Excusable delays, on the other hand, cannot be predicted and therefore the contractor is not liable to the owner for them. Excusable delays are then subdivided into compensable and non-compensable delays. Non-compensable delays grant the contractor an extension of time only, whereas compensable delays grant the contractor an extension of time as well as financial compensation.

The following page documents the Solaire Wheaton clauses associated with weather delays. Note the pieces of the clause that are highlighted in red, as these are the parts of most concern.

SOLAIRE WHEATON WEATHER CLAUSE

Weather – Contractor shall include in its schedule an adequate number of days to compensate for customary adverse weather conditions in the geographic area in which the project is located. No extensions of time will be granted because of days lost to normal adverse weather conditions. If "Extreme Weather Conditions" (defined herein as a weather event that results in adverse weather days in excess of the average number of adverse weather days for the project site for the applicable period of time, measured by data from NOAA over the last ten years for the twenty day period preceding the date of the weather event and the twenty day period following the date of the weather event within a 50 mile radius of the location of the project) are basis for a claim for additional time, such claim shall be documented by data substantiating the Extreme Weather Conditions and demonstrating that the Extreme Weather Conditions had an adverse effect on the critical path activities of the work. Contractor shall only be entitled to extensions of the Time(s) of Completion where it can demonstrate that Extreme Weather Conditions occur (as measured by data from NOAA over the last ten years for the twenty day period preceding the date of the weather event and the twenty day period following the date of the weather event within a 50 mile radius of the location of the project) and delay the critical activities of Work. All claims for extension of the Time(s) of Completion shall comply with the procedures and notice requirements set forth in the Contract Documents.

Bases for Extension - If Contractor is delayed in the performance of the Work by reason of, and only by reason of: (i) Extreme Weather Conditions (as and to the extent provided in Section 5.B.3 above); (ii) war or national conflicts or terrorism or priorities arising therefrom, fire, unavoidable casualties, or force majeure; or (iii) acts of Owner or the Architect (or an employee or agent of either) or a separate contractor engaged by the Owner, then the Time(s) of Completion shall be extended for a period equal to the length of such delay La critical path activities of the Work. Contractor shall, within ten (10) days after the commencement of any such delay, give written notice to Owner of the cause of any such delay and identify effected critical path activities. Within twenty (20) days after the conclusion of any such delay, Contractor shall request in writing a time extension for such delay demonstrating that the claimed delay arises from (i), (ii) and/or (iii) above, that the delay effected or is effecting the critical path activities of the Work, and identifying the length of such delay to the critical path activities. In order to quality as a delay to critical path activities for which an extension of time will be considered, the delay must result in a delay to the overall Project Substantial Completion Date. Owner may demand additional support for the claimed time extension from Contractor. Contractor's failure to give notice or to request a time extension in writing in accordance with this provision shall constitute a knowing waiver of any claim for an extension of time for the subject delay such that no ex tension of the Time(s) of Completion shall be granted for the subject delay. In the event of an extension of the Time(s) of Completion for (i) and (ii) above, no adjustment shall be made to the Guaranteed Maximum Price. In the event that a time extension is granted pursuant to (iii) above, Contractor's sale and exclusive remedy for such delay shall be: (i) the extension of time; and (ii) the Guaranteed Maximum Price will be increased by the actual cost of Work incurred by Contractor in connection with any such delay, provided that Contractor's Fee will not be adjusted.

Delay Must be Critical - In the event of any delay, it shall be Contractor's responsibility to prove to Owner that the delay to the Time(s) of Completion was caused specifically by a delay to the critical path activities of the Work.

ANALYSIS

With the aid of Jerry Pisarcik, Professor of the Legal Aspects of Engineering and Construction course and practicing civil lawyer, several issues were identified in the project's weather clause.

The first problem with the clause is the language, "measured by data from NOAA over the last ten years." NOAA produces their averages based on the total years of data collection for that area, which should be more accurate. Extensive work would be involved in pulling together data from only the past ten years, as NOAA does not produce their data in this way.

The next piece of language that raises concern is, "within a 50 mile radius of the project." Looking at the reports from all stations within a 50 mile radius would be tedious and unnecessary. It would be much simpler to utilize the reports of the nearest weather station.

The last part of the clause that is misleading reads: "the 20 day period preceding the date of the weather event and the 20 day period following the date of the weather event." The initial question that arises from this language is what constitutes a weather event? Next, is the determination process based on duration of the event or the proximity to recorded averages? The 20 day period piece of the language seems to be the most misleading and uninterpretable section.

These identified problems with the clause are the major source of confusion in the weather clause. These will be the major basis of change in recommendations for a specific and measurable weather clause.

Now the form contract clause language will be examined for ease of interpretation. The 2007 AIA 201 Standard Agreement 4.3.7.2 states, "If adverse weather conditions are the basis for a Claim for additional time, such Claim shall be documented by data substantiating that weather conditions were abnormal for the period of time, could not have been reasonably anticipated and had an adverse effect on the scheduled construction." Although this language is easier to understand, it is left open to interpretation by the drafter. The main questions that arise are: What constitutes abnormal weather conditions? Are all sources of weather data acceptable? This clause has too much gray area within the language.

Consensus Docs 6.3.1 states, "If the Contractor is delayed at any time in the commencement or progress of the work by any cause beyond the control of the Contractor, the Contractor shall be entitled to an equitable extension of the Contract Time. Examples of the causes beyond the control of the Contractor include…adverse weather conditions not reasonably anticipated; encountering Hazardous Materials…" This clause is more ambiguous than the AIA clause. According to this language, contractors are not compelled to produce any reliable weather data to support their claim for extension of time. It seems that the only thing to prove is that the weather conditions could not be reasonably anticipated.

As we have just seen, the form contract weather clauses are more interpretable; yet more ambiguous, making it unlikely to prove that work had been disrupted.

INDUSTRY TRENDS

The analysis will now look at some trends in the industry concerning weather clauses on construction projects. The following documentation is based upon the *Weather and Construction: The Contract* article by John Crane. According John Crane of Trauner Consulting, the form contract examples analyzed on the previous page leave us with the question of “what is considered to be ‘abnormal’ or could have been ‘reasonably anticipated.’”

In addition to historical data provided by the National Oceanic and Atmospheric Administration (NOAA), another reference may come from historical data accumulated by the contractor or owner that can be used to determine the number of “reasonably anticipated” weather days. Although using past project history to establish the “norm” could be more accurate, not many owners or contractors have this information collected.

There are a few factors to consider when estimating the number of “reasonably anticipated” weather days, such as the type of work and materials being used, the location of the project, and the different types of weather conditions that can occur during the project. These factors can drastically change this estimate. For example different soils react differently under certain weather conditions. Some soils take more rain to become unworkable than others, and some soils take longer to dry out. It may be advantageous to predetermine the amount of rain that make the soils unworkable. This issue applies similarly to cold temperatures, lightning, and high wind; however, organizations such as NOAA do not provide the data necessary to determine delays due to such events. To avoid the difficulty of establishing events such as dry out, it is recommended that the owner and contractor have an understanding of what is to be included in “reasonably anticipated.”

So what if the contract specifies average units of weather rather than days? The issue here is that this approach lacks clear guidance as to how many “reasonably anticipated” weather days the contractor should allow for in the project schedule, and how the “anticipated weather” days will be evaluated for any time extensions. This approach should still utilize the determination of a finite number of “reasonably anticipated” weather days for each month.

Finally what if the contract is silent with respect to "anticipated" weather days? As you saw from the contract weather clause, this is the case with the Solaire Wheaton project. If the contract does not identify the number of anticipated weather days or provide average units of weather in the contract documents, yet requires the contractor to consider the "norm" in its planned duration, the contractor will still need to account for these days in its project schedule.

The State of Tennessee provides a good example of a contract provision that attempts to avoid all confusion by simply telling the contractor to plan for the "norm." This provision sets a standard baseline of number of anticipated weather days for each month out of the year. It then proceeds to define adverse weather and weather delays days. Per this provision:

> "Adverse weather is defined as the occurrence of one or more of the following conditions within a twenty four hour day that prevents construction activity exposed to weather conditions or access to site:
>
> 1. Precipitation (rain, snow, or ice) in excess of one-tenth inch (0.10") liquid measure.
> 2. Temperatures that do not rise above that required for the day's construction activity, if such temperature requirement is specified as standard industry practice.
> 3. Sustained wind in excess of twenty-five (25) m.p.h.
>
> A Weather Delay Day may be counted if adverse weather prevents work on the project for fifty percent (50%) or more of the contractor's schedule work day and critical path construction activities were included in the day's schedule, including a weekend day or holiday if the Contractor has schedule construction activity on that day."

In conclusion, there are two popular ways to approach weather delays: as number of weather days which relies on a predetermined reasonably anticipated number of weather days, or as specific average units which relies on past weather data. No one way is right or wrong. It may be something that depends on the project scale and its stakeholders.

RESULTS

As the flowchart to the right in Figure 2.1 represents, the steps involved in the weather delay claim process include: written notice within 10 days, analysis and documentation, showing the effect on critical path, and written request for a time extension within 20 days. The analysis process for receiving an extension of time has two popular options for contract language. It is important for the project team to fully understand and follow the claim process requirements. The granting of time extensions due to weather will depend heavily on following the parameters of each of these steps. In this first analysis option, the weather must exceed monthly averages as established by NOAA. For these months that exceed the averages, the project team would then need to demonstrate adverse weather days by comparing planned and actual schedules, as well as using superintendent daily reports.

The project was examined in terms of monthly averages to determine if an extension of time due to excessive weather could be granted. Time extensions shall be granted if weather conditions exceed the monthly averages. Table 2.1 compares the recorded weather data and the monthly averages as reported by NOAA. This data received directly from NOAA can be found in Appendix A. As you can see October 2012, June 2013, and October of 2013 produced precipitation numbers in excess of the monthly averages, making these months available for a time extension. As noted before, the next step would be for the project team to demonstrate the weather delays using documentation.

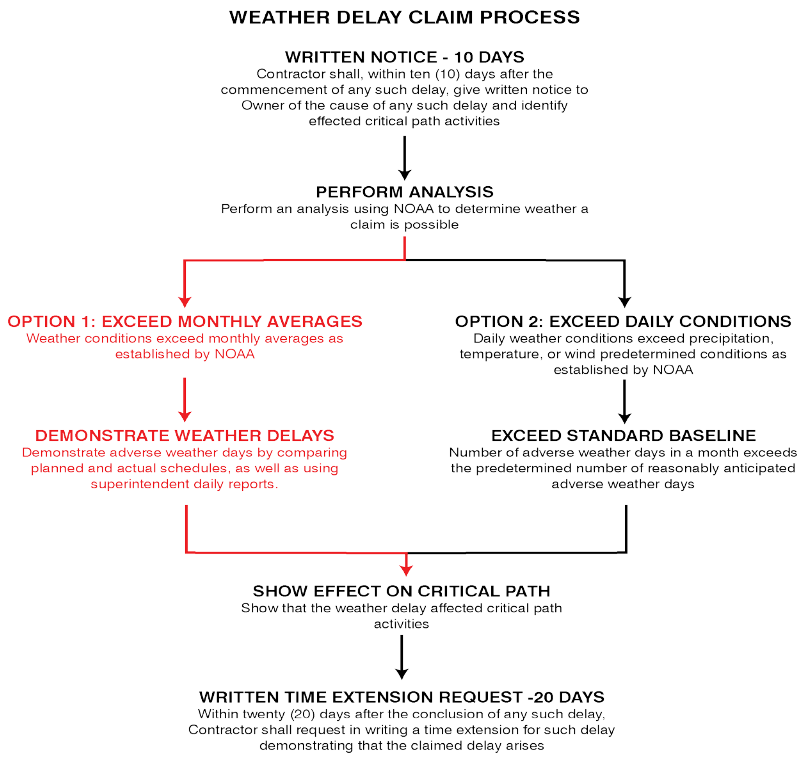


Figure 2.1. Weather Claim Flowchart Option 1

NOAA Precipitation (in.) Data			
Station: Silver Spring 0.9 N, MD US			
Month		NOAA Monthly Normals	Recorded Precipitation
2012	June	3.81	1.76
	July	4.85	0.63
	August	3.56	3.26
	September	4.00	1.39
	October	3.50	7.68
	November	3.51	0.87
	December	3.45	0.32
2013	January	2.96	1.90
	February	2.91	1.01
	March	3.46	1.00
	April	3.29	0.38
	May	4.40	2.35
	June	3.81	6.13
	July	4.85	1.97
	August	3.56	1.48
	September	4.00	0.10
	October	3.50	6.15
	November	3.51	2.35
	December	3.45	2.59

Table 2.1. NOAA Monthly Precipitation Data

The second popular contract language option for determining a time extension due to weather is shown in the flowchart to the right in Figure 2.2. This process follows the same general process as option 1, with the exception of the analysis step. If this analysis method is chosen, the project team and owner must agree ahead of time as to how many adverse weather days per month can be reasonably anticipated. This is subject to the typical weather conditions in the area of the location of the project. These reasonably anticipated weather days for the Solaire Wheaton project estimated in Figure 2.3 are to be built into the contractors schedule. For this analysis method, adverse weather conditions need to be defined ahead of time as well.

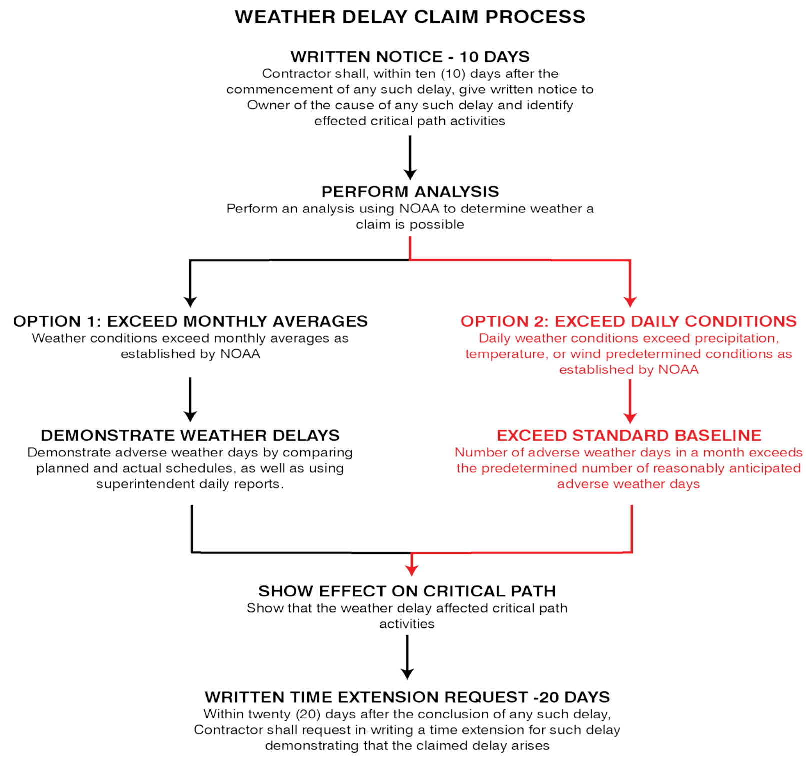


Figure 2.2. Weather Claim Flowchart Option 2

Month	Anticipated Weather Days
Janury	12
February	11
March	8
April	7
May	7
June	6
July	7
August	5
September	4
October	5
November	6
December	11

Figure 2.3. Anticipated Weather Days

This path for determining weather related time extension involves exceeding the baseline anticipated weather days. For the purpose of this analysis we will use the state of Tennessee's contract provisions which define adverse weather. This provision defines adverse precipitation in particular as liquid measure in excess of one tenth (0.10) inch. To continue with the time extension analysis daily weather data was gathered from NOAA, and can be found in Appendix A. Table 2.2 on the next page gathers the daily recorded precipitation data from the Silver Spring station. As you can see, there are several days in each month that exceed one tenth of an inch; however, the months that exceed the number of anticipated weather days are August 2012, October 2012, and June 2013. This produces a total of nine potential rain days. These do not include days granted for dry out of the soils, which would need to be documented and proven by the project team.

The final step for the contractor would be to prove that the adverse weather days affected the critical path activities. This could be done by comparing the planned and actual schedules, and showing proof using of weather delays the superintendent daily reports.

Precipitation (in.)																		
Station: Silver Spring 0.9 N, MD US 24 hour amounts ending at observation time																		
Day	**Jul. 2012**	**Aug. 2012**	**Sep. 2012**	**Oct. 2012**	**Nov. 2012**	**Dec. 2012**	**Jan. 2013**	**Feb. 2013**	**Mar. 2013**	**Apr. 2013**	**May 2013**	**Jun. 2013**	**Jul. 2013**	**Aug. 2013**	**Sep. 2013**	**Oct. 2013**	**Nov. 2013**	**Dec. 2013**
1	0.00	**0.14**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	**0.30**	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.18**	0.00	**0.10**	0.00	0.00	0.00
3	0.00	0.00	**0.11**	0.00	0.00	0.01	0.00	**0.84**	0.00	0.00	0.00	0.00	**0.13**	0.00	0.00	0.00	0.00	0.00
4	**0.10**	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.12**	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	**0.47**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
7	0.00	0.00	**0.11**	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	**1.75**	0.00	0.03	0.00	0.00	0.00	**1.14**
8	0.00	0.00	0.00	**0.14**	0.00	0.01	0.00	**0.12**	0.00	0.00	**0.87**	**0.82**	**0.19**	**0.12**	0.00	**1.28**	0.00	0.00
9	**0.20**	0.00	**0.88**	0.07	0.00	**0.14**	0.00	0.03	0.00	0.00	0.05	0.01	0.05	0.05	0.00	0.00	0.00	**1.10**
10	0.05	**0.65**	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.04	**0.53**	0.00	**0.24**	0.00	**0.48**	0.00	**0.22**
11	**0.27**	**0.19**	0.00	0.00	0.00	0.09	0.00	**0.39**	0.00	0.00	**0.50**	**1.33**	0.00	0.01	0.00	**1.47**	0.00	0.08
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**0.74**	0.01	0.00	0.00	0.00	**2.59**	0.00	0.00
13	0.00	0.00	0.00	0.00	**0.65**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.24**	0.00	0.00
14	0.00	**0.10**	0.00	0.00	0.08	0.00	0.00	**0.28**	0.00	0.00	0.00	**0.33**	0.00	**0.46**	0.00	0.02	0.00	0.00
15	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	**0.21**	0.00	0.00	0.00	**0.14**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	**0.28**	**0.20**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.07	0.00	0.00
19	0.00	0.00	0	**0.77**	0.00	0.00	0.00	0.00	**0.38**	0.00	0.02	**0.11**	0.00	0.04	0.00	0.00	0.00	0.00
20	0.00	**0.38**	0	**0.64**	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	**0.49**	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
23	0.00	0.02	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	**0.57**	0.00	**0.11**	0.00	0.00	0.00	0.00
25	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	**0.41**	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.02	0	0.00	0.00	0.00	0.05	0.00	**0.21**	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00
27	0.01	**0.43**	0	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	**0.25**	0.00	0.00	0.00	0.00	**2.28**	0.00
28	0.00	0.05	0	0.00	0.08	0.00	0.03	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.07	0.00
29	0.00	0.01	0	**0.63**	0.00	0.00	0.09	-	0.00	0.09	0.00	**0.31**	0.00	**0.35**	0.00	0.00	0.00	0.00
30	0.00	0.00	0	**4.94**	0.00	0.00	0.00	-	0.00	**0.29**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	-	**0.27**	-	0.00	**1.65**	-	0.00	-	0.00	-	0.00	0.00	-	0.00	-	0.00
Total Days	3	9	4	7	1	1	1	5	3	1	3	9	4	5	1	5	1	3
Anticipated Days	**7**	**5**	**4**	**5**	**6**	**11**	**12**	**11**	**8**	**7**	**7**	**6**	**7**	**5**	**4**	**5**	**6**	**11**
Potential Time Extension		**4**		**2**								**3**						

Table 2.2. Potential Adverse Weather Days

RECOMMENDATION

Based on the extensive analysis of weather clause language, the recommended clause would read:

"The contractor will be entitled to a time extension if the weather conditions at the jobsite are adverse and he can prove that the adverse weather conditions delayed activities on the critical path. Prior to the notice to proceed, the owner and contractor will agree on the amount of reasonably anticipated weather days that shall be built into the contractors schedule. Time extensions will only be considered for individual months. Total anticipated and total adverse weather days will not be considered when determining time extensions due to weather. Weather data shall be obtained from the nearest weather station to the project site.

Adverse weather conditions are defined as the occurrence of the following conditions:

(1) Weather conditions that exceed the standard baseline of reasonably anticipated weather days, and one or more of the following conditions as established by NOAA:

1. **precipitation (rain, snow, or ice) in excess of one-tenth inch (0.10") liquid measure.**
2. **temperatures that do not rise above that required for the day's construction activity, if such temperature requirement is specified as standard industry practice.**
3. **sustained wind in excess of twenty-five (25) m.p.h.**

(2)Adverse Weather may include, if appropriate, "dry-out" or "mud" days:

1. **resulting from precipitation days that occur beyond the standard baseline;**
2. **only if there is a hindrance to site access or sitework and Contractor has taken all reasonable accommodations to avoid such hindrance; and,**
3. **at a rate no greater than 1 make-up day for each day or consecutive days of precipitation beyond the standard baseline that total 1.0 inch or more, liquid measure, unless specifically recommended otherwise by the Designer.**

All claims for extension of the Time(s) of Completion shall comply with the procedures and notice requirements set forth in the Contract Documents."

This clause eliminates many of the ambiguities seen in previous examples of weather clauses. It also provides an equation for the person seeking retribution or an extension of time. This clause is more black and white. If two people were to interpret this language, the same result would be expected. As you can, these delays can be categorized as excusable and non-compensable.

MAE REQUIREMENTS

This analysis was informed by lessons taught in the AE 598D course, also known as Legal Aspects of Engineering and Construction. The course provided a general understanding of the owner and contractor agreement for a construction project. Although weather clauses were not an in-depth topic, the course analyzed other examples of trivial clauses such as differing site conditions and incorporation by reference. This graduate course enabled me to interpret clauses and understand the implications of minor differences in contract language.

CONCLUSION

Contract weather clauses are some of the most difficult within the contractor owner agreement to interpret. As we have seen, the form contract is not necessarily the answer to the self-written clauses that are not easily interpreted. It takes careful research and a combination of contract language from several sources to devise the best possible solutions. Each project has different parameters and clauses need to be tailored to fit these needs.

The best way to avoid litigation on a project is to put in the time up front to draft the most suitable and easily interpreted language. In the end, contract clauses should be like a simple math equation. If two people cannot arrive at the same result from contract language, then it does not perform its job.

CONSTRUCTION STUDY 2 – CRITICAL INDUSTRY ISSUE: BIM FOR SAFETY ORIENTATION

PROBLEM IDENTIFICATION

A major issue in the construction industry today is the site specific safety orientation of workers. On a typical project, workers are often trained in orientation using a "generic" safety video which is normally produced by the general contractor or construction manager's safety management staff. Although these safety videos have some relevant lessons, they also present many irrelevant topics that do not pertain to the current project. Consequently, these workers are no more prepared to avoid the project specific safety hazards than when they arrived on site, as they don't know what hazards to be aware of and where they are located. Construction projects are continuously becoming more complex, and new safety hazards will always be emerging.

The construction manager on the Solaire Wheaton project utilized a contractor controlled insurance program (CCIP), which is a policy where all the participants on a building project are covered by a single policy. Although this policy can lower insurance rates of the subcontractors with poor experience modification rates (EMR), it also adds to the risk that the construction manager assumes. In this case especially, where the CM assumes more risk of accidents, the construction manager needs to step up to the plate and devise a new approach to safety orientation.

Safety orientation is the first opportunity to make a good impression on the workforce. It is important to show them that as the construction manager, you care about their safety and well being and are taking a preventative approach rather than a reactive approach. Accidents can happen to even the most experienced and trained workers who are not prepared to deal with site specific safety hazards that are not addressed in generic training. A good number of injuries could be avoided by identifying these hazards before they are encountered and presenting them to workers in safety orientation.

Generic safety videos used for orientation on construction projects typically has a duration of half an hour. If this time is used to simply communicate generic safety topics that most workers have learned on prior projects time and money is being wasted. As you can see in Figure 3.1, with an estimate of 400 workers going through orientation on the Solaire Wheaton project, there is 200 lost hours. If we then assume that the average employee costs a company $45.00 per hour, this results in $9,000 of lost money through the duration of the project. This time and money needs to be translated into effective site specific safety training. To maximize this effectiveness, all tools need to utilized including building information modeling.

Ineffective Safety Orientation Lost Time Calculation	
400	Estimate of total workers through orientation
$45/hr	Estimated average houry cost for employee
1/2 hr	Typical duration of safety orientation video
200	Estimated hours of lost time
$9,000	Estimated cost for ineffective safety orientation

Figure 3.1. Lost Time and Money Calculation

RECENT INDUSTRY TRENDS FOR SAFETY

The NYC Department of Buildings is at the forefront of creating change in how construction safety is analyzed and planned. In 2012 they unveiled a safety initiative that encourages contractors working on large projects to submit 3D site safety plan. This initiative makes the City's Building Department one of the first to accept and review safety plans in this manner. Following this, in July of 2013, NYC Buildings created *Version 1.0 of the Building Information Modeling Site Safety Submission Guidelines and Standards* (BIM Manual). According to the NYC Building Department, this document "allows design professionals to electronically create and file site safety plans - better enabling the department and industry to collaborate on strengthening construction site safety." Site safety modeling in 3D allows for increased safety, faster approvals, and better service. The Online document management website allows for submissions to be reviewed, modified, and improved in a more efficient manner. According to an article in Todays Facility Manager, site safety plans are required for the city's largest construction projects before permits can be issued. The city's largest construction projects includes: new buildings 10 stories or higher, gut renovations of 10 stories and higher involving mechanical demolition, facade renovations of buildings 15 stories and higher, and buildings with a footprint of 100,000 square feet or more.

The BIM standard sets forth that 3D models are expected to contain the same information and detail as the existing 2D submittals per Chapter 33 of the NYC Building Code and DOB requirements. Submissions must address all elements in the following categories: site and egress (traffic flow, fire department access), street furniture (signs, fire hydrants), construction (existing building heights, crane pads), and excavation/foundation (ramps and protection of utilities). The program also makes a multitude of model elements or families available to use in the site safety model including equipment and site logistic elements.

At the time of the Build Safe|Live Safe Conference in June of 2013, NYC Buildings had reviewed 147 3D site safety plans consisting of 23 projects. This conference was held to illustrate the advantages of BIM for site safety planning. As shown in Figure 3.2 to the right, BIM is being utilized at many different levels in the industry. Although it is becoming more of a common tool in the building industry, these results show that 32% of participants in the survey still use BIM on zero percent of their projects. The major companies utilizing BIM are implementing the design clash detection and 4D sequencing tools. If BIM for site specific safety orientation is to become one of these tools it will have to start at the top and trickle down.

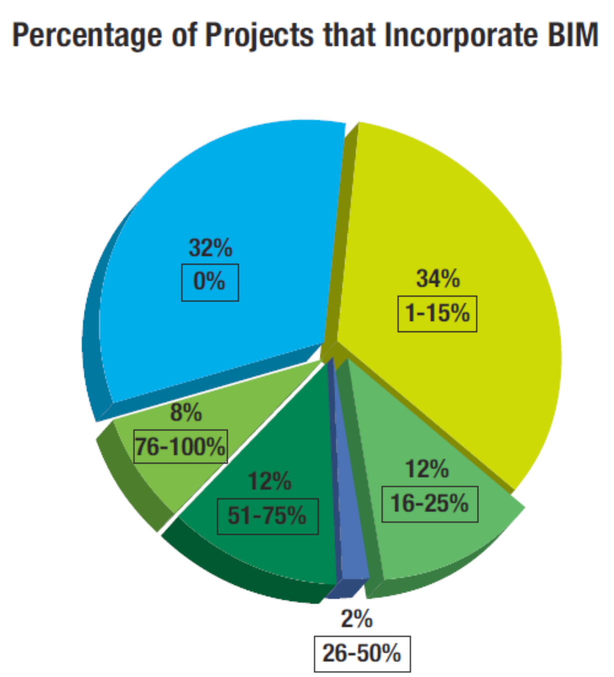


Figure 3.2. Percentage of Projects that Incorporate BIM
Source: 2013 Grossi & Co. A&E Outlook Survey

Grossi & Company also performed a study within the construction industry concerning the affect that BIM has on firms. The results can be seen in Figure 3.3. You can see that 58% of the interviewees responded that BIM decreased the risk for their firms. The risks that these interviewees describe are most certainly related to clashing of trades, improper sequencing, and proper as-builts. One that is more than likely not reflected in this survey is the decreased risk of injury or death due to BIM safety training and orientation; however, this has the ability to be a great contributer to decreasing risk. You can also see the overwhelming 97% response that BIM increased the quality of services provided to the client. Interestingly 52% believe that BIM decreased their profitability. This is a difficult metric to look at because owners are generally unwilling to pay extra for BIM on a project, and construction companies may not be able to clearly see the profit increases. The industry will continue to adapt in how it utilizes building information modeling. New theories and methods of utilization continue to unfold each year, and these survey results are bound to change accordingly.

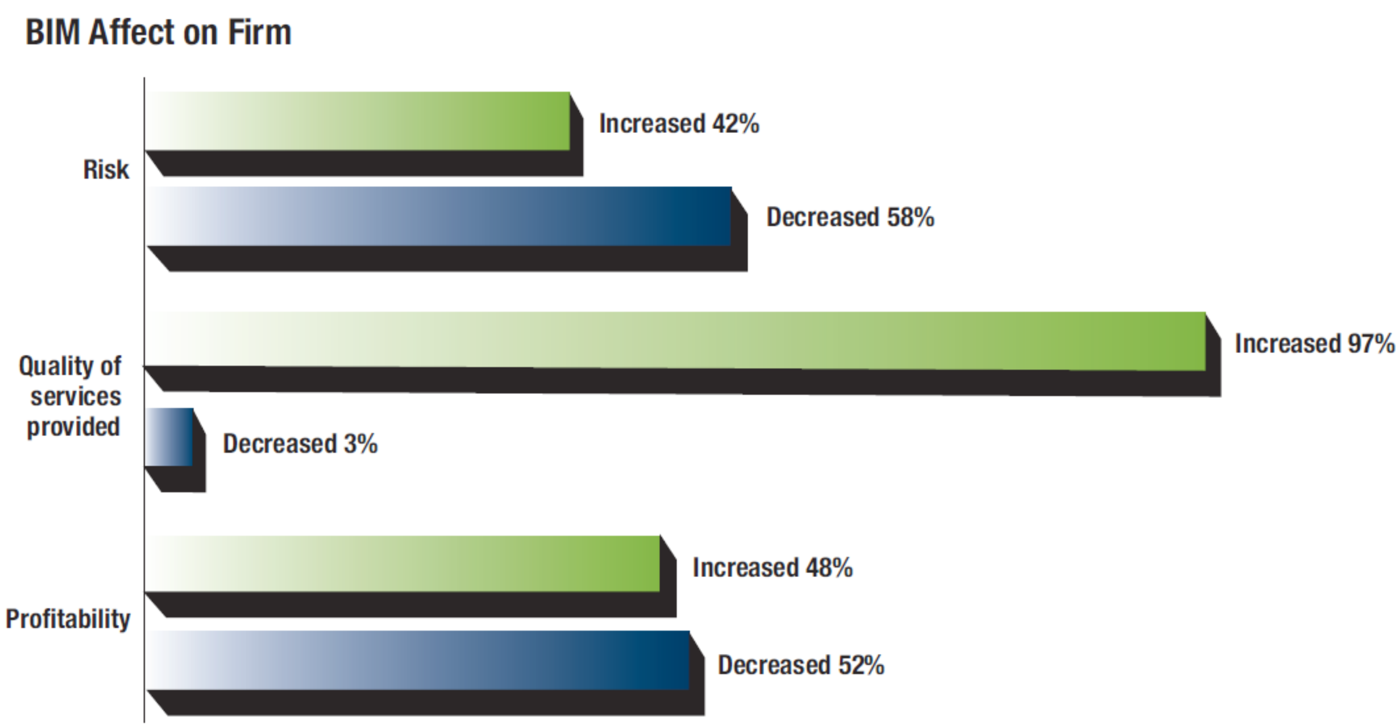


Figure 3.3. BIM Affect on Firms
Source: 2013 Grossi & Co. A&E Outlook Survey

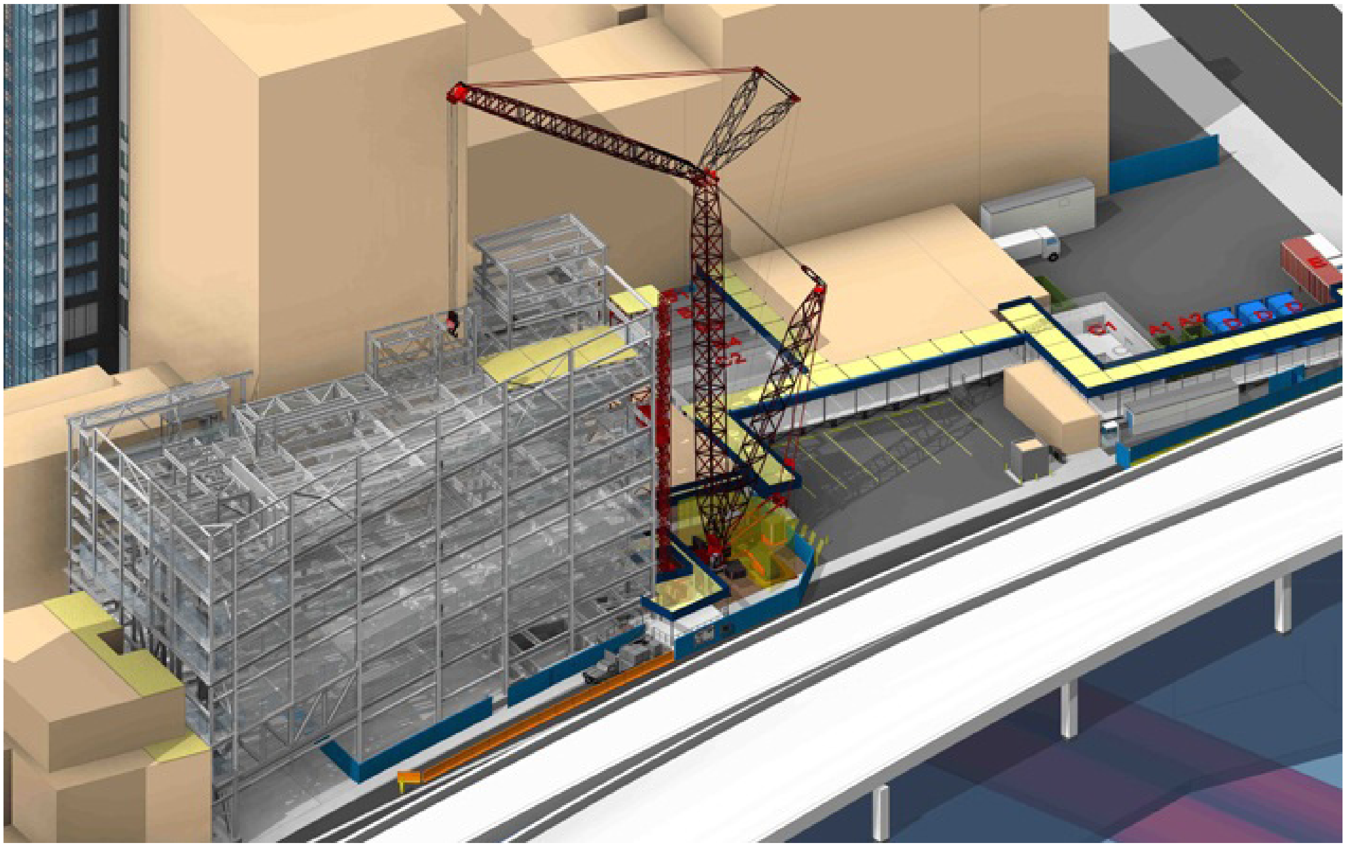


Figure 3.4. BIM Affect on Firms
Source: https://www.turnerconstruction.com/news/item/2dc5/New-York-City-Department-of-Buildings-Approves-First-Three-Dimensional-BIM-Site-Safety-Plans

According to a 2012 article on the Turner Construction website, Turner became first company to have their three-dimensional Building Information Model-based plans approved by the New York City Department of Buildings. Three-dimensional BIM site safety plans seen in Figure 3.4 enable building inspectors to take virtual tours of construction projects and review them in real time on the construction site. Commissioner of the New York City Department of Buildings, Robert LiMandri said: “The use of 3D site safety plans is a revolutionary step toward improving construction safety.”

Turner created the plans, which show the locations of site fencing, perimeter protection, cranes, hoists and other equipment and materials – using detailed Building Information Modeling tools, and submitted them to the Department of Buildings electronically in both 3D and 2D formats. Digital submission follow-up required fewer office visits and expedited the approval process as the 3D images enhanced communication between field inspectors, office supervisors and Turner. Most importantly, the virtual models and walkthroughs helped identify potential safety risks earlier in the review process, before the start of construction.

RESEARCH & ANALYSIS

This analysis will look at ways to use building information modeling (BIM) to present safety information and lessons to the workers during orientation who are performing the work and will encounter these hazards. The building information modeling elements of safety orientation are not intended to replace current safety training but to supplement the orientation and training effectiveness. The information in the BIM graphics will be related to project specific hazards and be applicable once people walk on site to perform or observe work. This approach will then be compared to the current approaches to safety orientation.

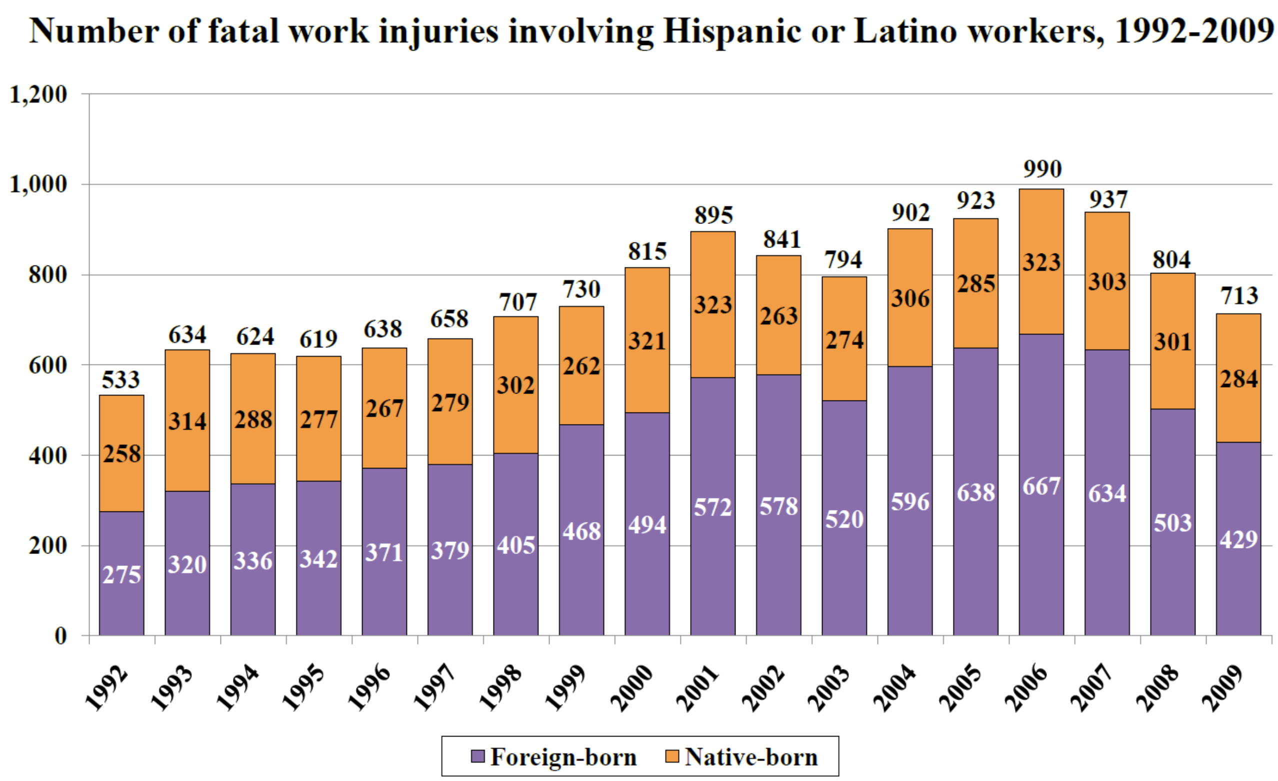
Through extensive research, three main problems have been identified as contributors to the ineffective safety training and orientation of workers. The language barrier associated with a growing foreign born workforce, the low level of education of workers, and the inability to create visuals for relevant safety information all contribute greatly to the inability to effectively prepare the workforce, .

If a poll was taken of the workforce's view on safety orientation, results would show that a number of workers have seen the information presented in the videos time and again in different forms. According to the study *Why Operations Engage in Unsafe Work Behavior:* When an interviewee was asked how his workmates react to safety training, he responded they just sign their names on the training sheet and then walk away, saying ''it is boring and wastes their time.'' This indicates that workers' attitude toward safety training and orientation is not positive. Hearing that safety training wastes somebody's time indicates that they do not see a return from the training. This goes back to the generic video that presents the same information over and over and that experienced workers have seen enough times to have memorized. The current approach to safety training and orientation is not challenging the workers. Orientation becomes an antagonizing routine and more of a chore than an aid.

The ability to see a problem before it is encountered is extremely valuable and is not currently being utilized at the level possible. If there was a way to visually present safety information that is specific to the project, workers will be more likely to remember the lessons, and avoid hazards.

Arguably the biggest problem associated with safety in construction is the language barrier. With a growing diversity of population and construction workers in general, communication is becoming a growing issue on job-sites. Safety managers who can speak multiple languages and communicate effectively with all workers are few and far between. Many safety videos do have the option of playing in either English or Spanish; however, what happens when part of an orientation crew only speak Spanish and the other half only speak English? It is doubtful that the orientation is given in two groups to accommodate both languages.

As illustrated in Figure 3.5, the number of native born fatal work injuries has remained steady, while the foreign born work related injuries have risen fairly consistently. The number of injuries involving foreign born workers has been more than double that of native born workers in recent years. These statistics prove that safety information is not being communicated effectively to the foreign born workforce.



Fatal work injuries involving Hispanic or Latino workers continued to decrease in 2009 after reaching a series high in 2006. About three-fifths of fatally-injured Hispanic or Latino workers in 2009 were born outside of the United States.

Figure 3.5. Number of Fatal Work Injuries Involving Hispanic or Latino Workers, 1992-2005
Source: US Department of Labor, Bureau of Labor Statistics, Census of Fatal Occupational Injuries, 2005.

Through online research, it was discovered that the OSHA 1926 Construction Manual does not seem to be available in languages other than English, including Spanish. In order to change these statistics it is paramount to have trained multilingual field supervision and safety management staff. In addition, having the ability to adapt safety orientations into suitable languages is imperative. No worker should be denied safety orientation because of the language barrier.

One of the major problems that can arise on a jobsite with space restrictions for material staging and movement is equipment getting too close to power lines. Although this is addressed in many safety trainings and orientations, this is difficult to avoid sometimes. Workers can forget to look overhead before moving a lift or crane. This is a very serious issue as overhead power lines can cause serious injury or death. Subpart O, section 1926.600 (a)(6) states:

> "All equipment covered by this subpart shall comply with the following requirements when working or being moved in the vicinity of power lines....
>
> (i)For lines rated 50 kV or below, minimum clearance between the lines and any part of the crane or load shall be 10 feet.
>
> (ii) For lines rated over 50 kV, minimum clearance between the lines and any part of the crane or load shall be 10 feet plus 0.4 inch for each 1 kV over 50 kV, or twice the length of the line insulator, but never less than 10 feet."

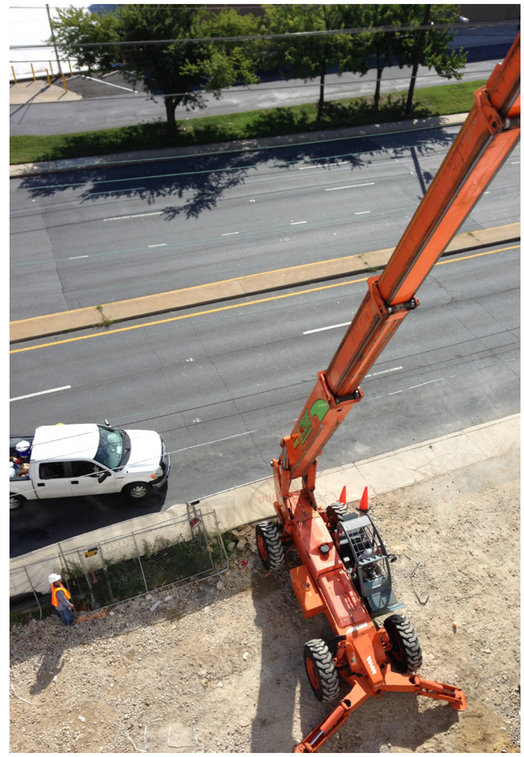


Figure 3.6. Forklift Proximity to Power Lines

As you can see in Figure 3.6 this was a real problem on the Solaire Wheaton project. The site could only be accessed on the East side and there is not much setback of the building from the road. With the assumption that the power lines are below 50 KV, you can see that the forklift has come well within the required 10 foot distance from the power lines.

The training of maintaining a required distance from overhead power-lines can be approached in many different ways. Figure 3.7 is taken from a generic safety orientation video and demonstrates keeping a boom lift away from the power lines. The problem with this is that it is not specific to the project. The location of power lines on the specific project is not identified nor are project specific situations illustrated where the hazard may be encountered.

Figure 3.7. Generic Safety Orientation Video

An additional problem is that the video does not allow the viewer to visualize the minimum distance requirement. The narrator of the video explains that the minimum distance requirement is 10 feet, but you will see that only 11% of what we learn comes from what we hear. It would be easy to be distracted during the video and miss the audio description of the minimum 10 foot requirement.

This power line example is one of the many hazards that can be identified using building information modeling technology during the design review process. Using the images presented below, the project team can identify that using a forklift as a means of loading the building of material will put workers in danger and change the plan. In this case a material hoist, although hindering enclosure progress and potentially delay the schedule, would be a safer means of transporting material vertically.

Should this hazard not be caught in the design stage, these BIM generated images can be used as a teaching tool during safety orientation for operators of the forklift. The project team can warn them that they may not be able to reach the top floor with the lift or that they may need to come in at an angle to stay clear of the power lines.

Figure 3.8 presents a way to distribute information from the OSHA 1926 Construction Manual in an effective way to multilingual audiences. In this case, building information modeling made it possible to visualize the hazard and inform all workers on how to properly deal with it.

English - OSHA 1926 Subpart O, section 1926.600 (a)(6):

"All equipment covered by this subpart shall comply with the following requirements when working or being moved in the vicinity of power lines....

(i)For lines rated **50 kV or below**, **minimum clearance** between the lines and any part of the crane or load shall be **10 feet**.

(ii) For lines rated **over 50 kV**, **minimum clearance** between the lines and any part of the crane or load shall be **10 feet plus 0.4 inch for each 1 kV over 50 kV**, or twice the length of the line insulator, but never less than 10 feet."

Spanish - OSHA 1926 Subpart O, section 1926.600 (a)(6):

"Todo equipamiento cubierto por esta sub-parte deberá cumplir con los siguientes requerimientos cuando trabajando o siendo movido en la vecindad de lineas de alta corriente....

(i) Para lineas calificadas **50kV o menor, la distancia mínima** entre las lineas de alta corriente y cualquier parte de la grúa o carga deberá ser de **10 pies.**

(ii) para lineas calificadas por **encima de 50 kV, la distancia mínima entre** las lineas de alta corriente y cualquier parte de la grúa o carga deberá ser de **10 pies mas 0.4 pulgadas por cada 1 kV por encima de 50 kV**, o doble la medida del aislamiento de la linea, pero nunca menos de 10 pies."

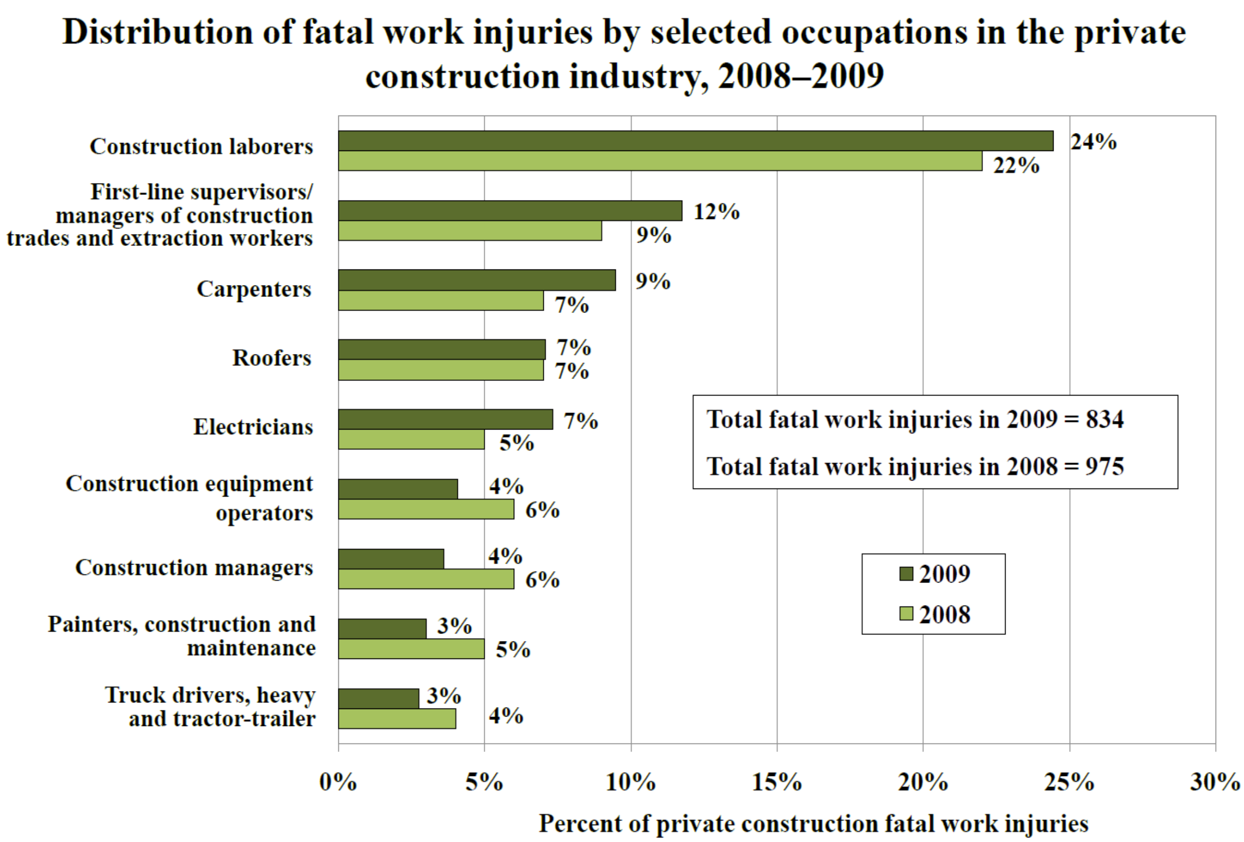
Figure 3.8. Forklift Power Line Hazard Recognition

Education is another underlying problem in construction safety orientation. According to the study, *Why Operations Engage in Unsafe Work Behavior: Investigating factors on Construction Sites*, an interviewee revealed that training was a waste of time because he could not understand its contents. The worker said that he did not know about the scheduling of safety meetings. He explained that he was an uneducated person and could only write his name, stating “I cannot read safety material.”

Much of current safety orientation information is in written form. With the current level of technology, more effective ways of presenting safety information need to be implemented. Workers who cannot read and/or are inexperienced and uneducated in safety principles need to be considered.

As shown in Figure 3.9, the highest percentage of fatalities in the private construction industry derive from construction laborers. Totaling approximately one fourth (25%) of the private construction fatalities, this group should be of major concern during safety orientation. Construction laborer is typically an entry position in the construction workforce consisting of less skilled and less educated workers.

Art and graphics are very powerful communication tools for communicating ideas and concepts to largely illiterate people.



Fatal work injuries involving construction laborers accounted for about one out of every four private construction fatal work injuries in 2009. Total fatal work injuries in construction declined by 14 percent from 2008 to 2009.

Figure 3.9. Distribution of Fatalities Across Occupations in the Private Construction Industry
Source: US Department of Labor, Bureau of Labor Statistics, Census of Fatal Occupational Injuries, 2005.

A major example of workers with little education not being prepared to work safely on a jobsite is the job trailer posting of directions to the nearest hospital or medical center. The issue is that these directions are typically in written form, and workers that are not educated in reading and writing may not be able to use this information in the case of an emergency.

To the right in Figure 3.10 is an example of what a hospital direction posting in a typical job trailer might look like. As you might notice this is not the best way of illustrating where the nearest hospital is located. A worker that is attempting to get a fellow worker to immediate care is sure to be in a rush and may be panicking. As most construction workers do not live within close proximity to their jobsites and must travel, there will be unfamiliar with the area. In addition, if the employees are uneducated in reading and writing, this information does nothing to direct them to care for an injury.

Hospital Directions

(Silver Spring Medical Center, LLC.)

Address: 11301 Amherst Avenue #102, Silver Spring, MD

1. Head south on Georgia Avenue towards Interstate 495
2. Make a U-turn and head north on Georgia Avenue
3. Turn right onto Prichard Road
4. Turn left onto Amherst Avenue
5. Medical Center will be on the right

Figure 3.10. Typical Job Trailer Hospital Directions Posting

Figure 3.11 presents another approach to posting hospital directions. Although this is a better way to present this information than Figure 3.10, there are some flaws. The Solaire Wheaton project was in a blossoming metropolitan area with several construction jobs nearby including a high rise job which is located between the Solaire project and the medical center. With the narrow adjacent roads to the project, the contractor would occasionally shut down the adjacent road during major deliveries. The problem with this approach is that Google maps does not know when a road is shut down. The hospital directions could lead workers into a dead end if they are simply copied from an online map website.

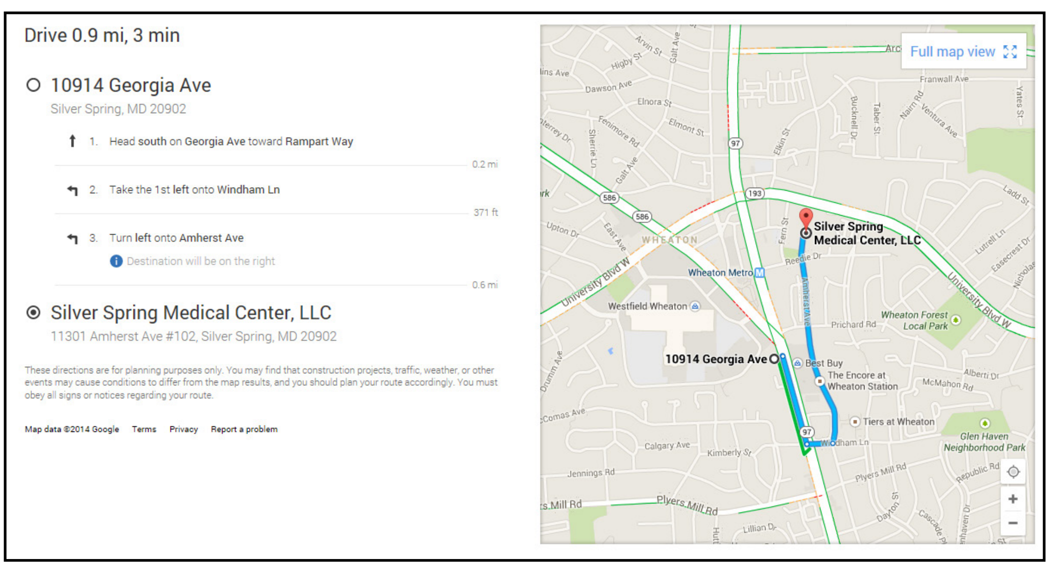
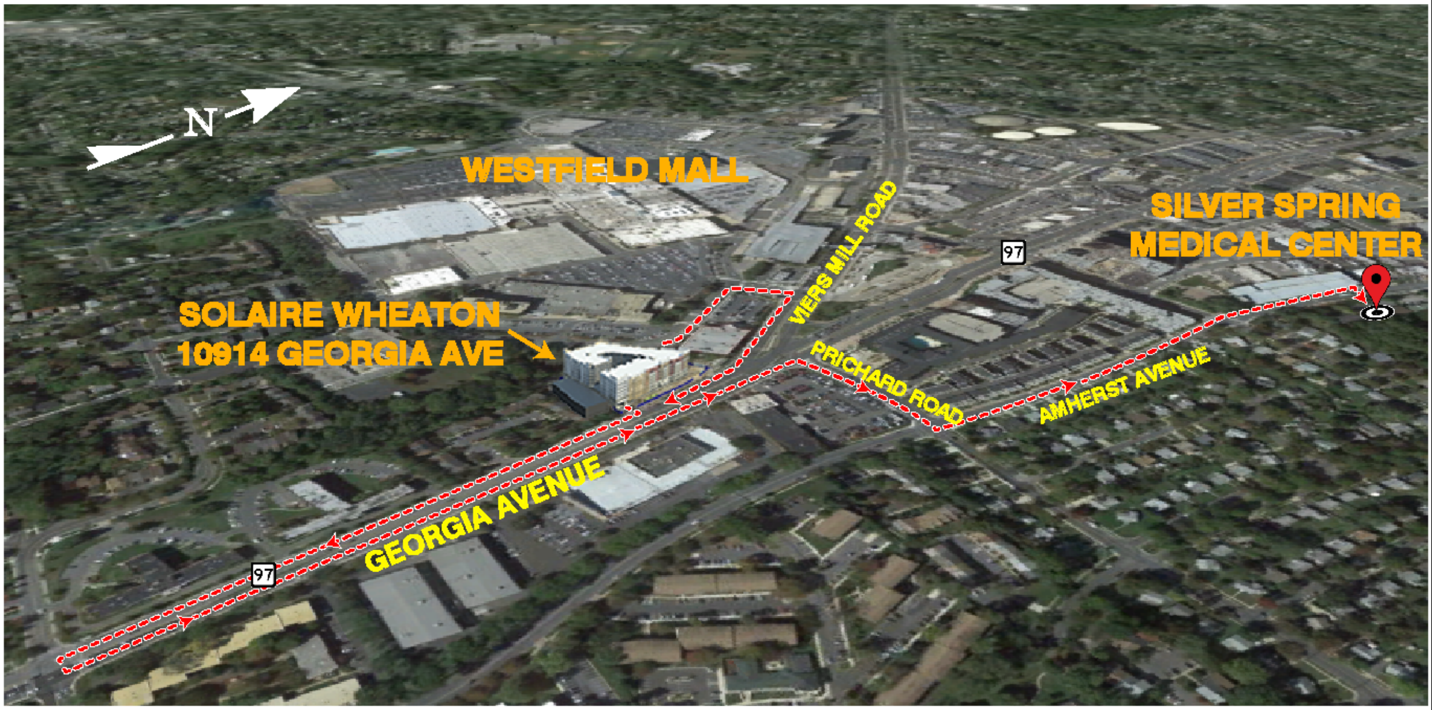


Figure 3.11. Google Map Hospital Direction Posting

Figure 3.12 below illustrates how a BIM model can be used to present a 3D representation of hospital directions from a construction site. As a BIM model is often used for 3D coordination and 4D sequencing, much of the modeling work has already been completed. In addition to having the ability of customization for different languages, this approach makes a trip to the medical center easier to accomplish.

EMERGENCY MEDICAL CENTER DIRECTIONS



ENGLISH

1. Head south on Georgia Avenue toward Interstate 495
2. Make a U-turn and head north on Georgia Avenue
3. Turn right onto Prichard Road
4. Turn left onto Amherst Avenue
5. Medical Center will be on the right

SILVER SPRING MEDICAL CENTER, LLC.
11301 AMHERST AVENUE #102, SILVER SPRING, MD

SPANISH OR OTHER TRANSLATED LANGUAGE

Figure 3.12. BIM Model Hospital Direction Graphic

As noted, the final major problem with construction safety orientation is that there is currently an inability to create effective visuals illustrating safety hazards. Workers are unable to visualize how work is to be conducted and determine how to properly avoid these hazards.

According to Mike Markel's Technical Communication textbook, "some 83% of what we learn derives from what we see, whereas only 11% derives from what we hear (Gatlin, 1988)."

Orientation videos show workers common safety precautions but in no way orient them with the specific project. One example of under-utilizing visuals is in the emergency egress plan. Projects that must develop project specific safety plans typically will address an egress plan. Subpart C of OSHA 1926 addresses employee emergency action plans. It reads:

(a) Scope and application. This section applies to all emergency action plans required by a particular OSHA standard. **The emergency action plan shall be in writing** and shall cover those designated actions employers and employees must take to ensure employee safety from fire and other emergencies.

(b) Elements. The following elements at a minimum shall be included in the plan:

- **(1) Emergency escape procedures and emergency escape route assignments;**
- (2) Procedures to be followed by employees who remain to operate critical operations before they evacuate;
- **(3) Procedures to account for all employees after emergency evacuation has been completed;**
- (4) Rescue and medical duties for those employees who are to perform them;
- (5) The preferred means of reporting fires and other emergencies;
- (6) Names or regular job titles of persons or departments who can be contacted for further information or explanation of duties under the plan;

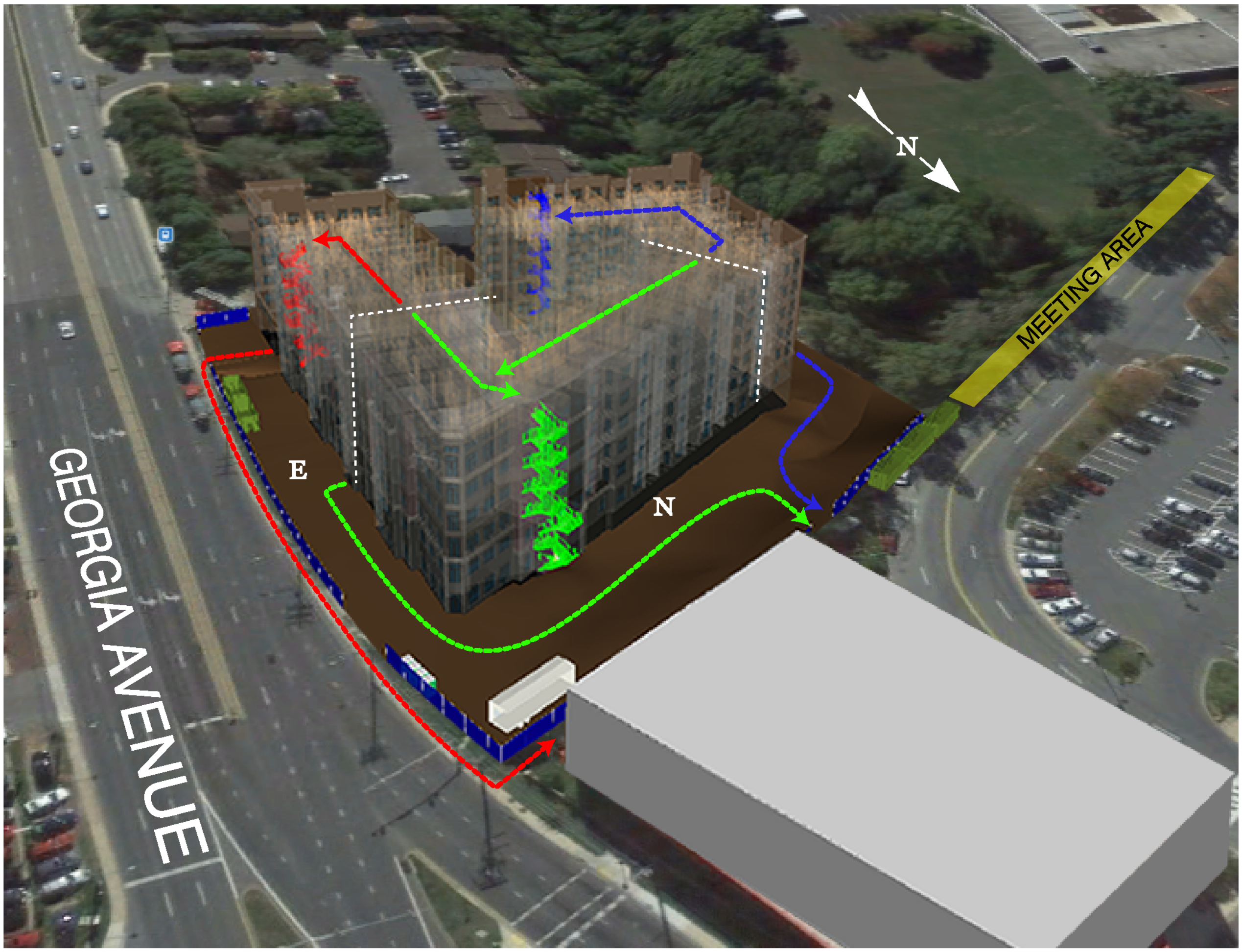
(c) Alarm System.

- (1) The employer shall establish an employee alarm system which complies with 1926.159
- (2) If the employee alarm system is used for alerting fire brigade members, or for other purposes, a distinctive signal for each purpose shall be used.

(d) Evacuation. The employer shall establish in the emergency action plan the types of evacuation to be used in emergency circumstances.

Although OSHA states: "the emergency action plan shall be in writing," graphic visuals allow for a more effective way of presenting this information. Figure 3.13 on the following page shows an approach to using building information modeling graphics to illustrate an emergency egress plan on the Solaire Wheaton project. This addresses each of the major problems: the language barrier, the inability of uneducated workers to read safety information, and the inability to create effective visuals.

EMERGENCY EGRESS PLAN



Stair A	Stair B	Stair C
-Acesses floors 1 through roof -Only stairwell with roof access -Exit stairwell on the south side -Turn right and proceed to the southwest corner -Turn right and follow along the west side -Exit site on the north and proceed to meeting area	-Acesses level P2 to 6th floor -Exit stairwell and proceed to the lobby -Exit building on the east elevation -Turn left and proceed to the north side of the building -Exit site and proceed to meeting area	-Accesses motor court to 6th floor -Exit site through the garage entrance -Turn left and follow the outside of the fence -Turn left between the fence and the LA Fitness -Proceed to the meeting area

Figure 3.13. Solaire Wheaton Emergency Egress Plan

As you can see building information modeling can be used in many different ways to present safety information; however, it is difficult to determine the value of BIM safety orientation without actual implementation of these methods.

Table 3.1 compares the two safety orientation approaches in their applicability to the Solaire Wheaton project. This comparison shows that building information modeling is more easily adaptable and therefore can more closely align with the project than the generic safety video. The table breaks down each subpart of the OSHA 1926 Construction Manual. Although the generic safety video does address many of the Solaire Wheaton project's safety topics, it is important to note that they may not be project specific. In other words, the generic safety video does not orient workers to the specific project.

Safety Topic Applicability				
OSHA Section	**Topic**	**Solaire Wheaton Project**	**BIM Orientation Capability**	**Generic Safety Orientation Video**
Subpart A	General			
	Safety Statistics (# of fatalities, etc.)			
Subpart B	General Inrepretations			
Subpart C	General Safety & Health Provisions			
	Means of Egress (Fire Egress Plan)			
Subpart D	Occupational Health and Environmental Controls			
	Hospital Directions			
Subpart E	Personal Protective Equipment			
Subpart F	Fire Protection (Fire Extinguisher Locations)			
Subpart G	Signs, Signals, Barricades			
Subpart H	Materials Handling, Storage, Use, and Disposal			
Subpart I	Tools - Hand and Power (Extension Chords)			
Subpart J	Welding and Cutting			
Subpart K	Electrical			
Subpart L	Scaffolding			
	Pump Jack Scaffolding			
	Aerial Lifts			
Subpart M	Fall Protection Safety			
Subpart N	Cranes, Derricks, Hoists, Elevators			
Subpart O	Vehicles & Equipment (Proximity to Overhead Power Lines)			
Subpart P	Excavation and Safety Trenching			
Subpart Q	Concrete & Masonry			
Subpart R	Steel Erections			
Subpart S	Tunnels and Shafts, Caissons, Cofferdams, and Compressed Air			
Subpart T	Demolition			
Subpart U	Blasting and Use of Explosives			
Subpart V	Power Transmission and Distribution			
Subpart W	Rollover Protective Structures; Overhead Protection			
Subpart X	Falls from Ladders			
Subpart Y	Commercial Diving Operations			
Subpart Z	Toxic and Hazardous Substances			

Table 3.1. Safety Orientation Value Comparison

CONCLUSION

As building projects become more complex, the industry continues to develop new engineering, sustainability, scheduling, and cost saving strategies. Safety is next in line and in major need of a new modern approach. According to part one of version one (page 20) of the *National Building Information Model Standard*, building information modeling can be defined as: "a product or intelligent digital representation of data about a capital facility." The graphics presented in this analysis are an intelligent digital representation of safety information.

BIM has been used in the past to perform constructability reviews during design. You have now seen how building information modeling is beginning to be used to more efficiently collaborate with city officials during planning, but it had not yet made its impact on the communication of safety during the construction phase.

One of the major issues is in the flow of safety information on the jobsite. Safety information is generally posted in the job trailer which is accessible by the work supervisors or are locked away in some filing cabinet. When people get a new job in other industries, they are given an orientation packet to familiarize them with the company and the tasks and rules of the job. Construction safety should take this approach to inform workers of site specific safety information during their orientation. The orientation packet could include general rules such as no smoking in the building, what elements of personal protective equipment are required, etc followed by building information model derived emergency action plans and safety hazard recognitions.

In supplement of the current safety orientation approach, the building information modeling approach can be used to: break the language barrier, inform illiterate workers, and effectively create visuals which account for 83% of what we learn.

CONSTRUCTION STUDY 3 – MODULARIZATION

PROBLEM IDENTIFICATION

The factor that is most critical to the success of the Solaire Wheaton project is meeting schedule deadlines and substantial completion. As seen in Figure 4.1, there is a high-rise apartment building being constructed a few blocks north on Georgia Avenue as well as a recently constructed mid-rise apartment building across the street. The apartment rental market in the Wheaton area is becoming increasingly competitive with the addition of these new complexes. The apartment building being constructed down the street was following along at a similar pace and would be completed soon after the Solaire project. Had there been a way to accelerate the schedule and complete construction sooner, the marketing team would have a better opportunity to lease units. There have also been delays related to weather, lead times, design changes, and inspections, increasing the risk of on-time completion of the project. On-site productivity is also being driven down by the site constraints, aggressive schedule demanding increased manpower, and stacking of the trades.

One area of the project that has potential for schedule acceleration is the structural wood framing and MEP rough-in of floors two through six. Using stick-built methods during these stages requires excessive amounts of time for vertical and horizontal transportation of materials and waste. The site constraints cause the building to be loaded in the southeast corner of the building and be transported all the way around to the southwest corner of the building. This is an extensive waste of time and labor.

The third analysis will evaluate the use of modularization, and determine if implementation on the Solaire Wheaton project is feasible. Modularization allows project teams to integrate the design and construction phases. Construction of the modules can take place during the foundation and cast-in-place concrete phases of the project. Modularization has many benefits including schedule and safety hazard reduction, elimination of waste, and increased field productivity.

Figure 4.1. Nearby Apartment Buildings

BACKGROUND RESEARCH

Modular construction is an innovative construction technique which utilizes off-site fabrication of modules, while on-site work occurs concurrently. This significantly shortens the overall construction duration while allowing for earlier building occupancy. According to the modular construction institute, and a seen in Figure 4.2, modularization has the potential to reduce the construction schedule by 30% to 50%. Commercial Modular Construction Services reports that most modules arrive at the site 60-90% complete with structural and MEP systems installed and inspected.

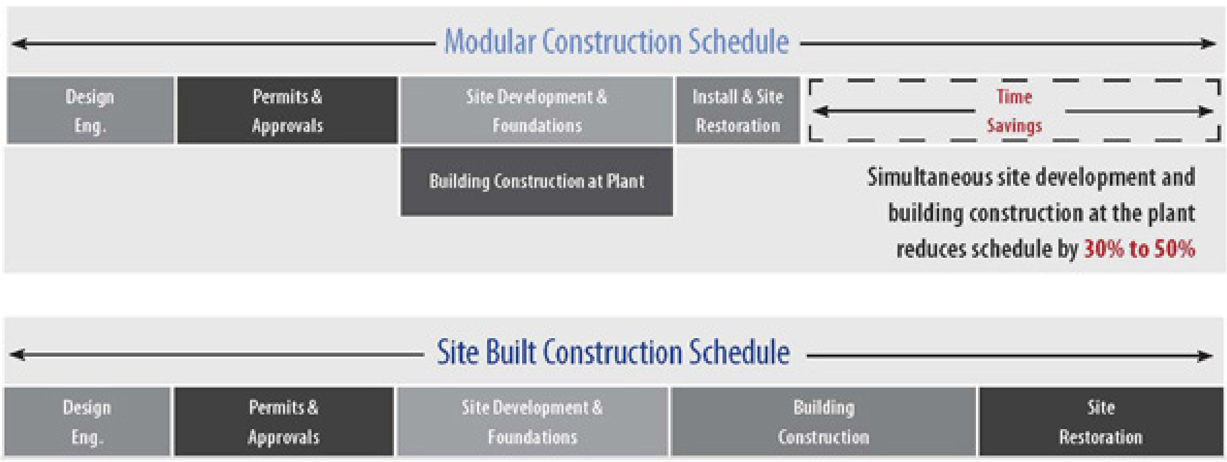


Figure 4.2. Modular Construction Schedule
Source: http://www.modular.org/htmlPage.aspx?name=Offsite_Construction_Equal_Green

Wood modules are constructed in an off-site warehouse space as seen in Figure 4.3. Here the quality of workmanship can be better controlled as they are checked before they are transported. Modular construction methods allow for a second phase of quality control as they are checked once they arrive on the jobsite to make sure there was no damage during transportation.

Figure 4.3. High-Rise Modular Wood Construction
Source: http://continuingeducation.construction.com/article_print.php?L=5&C=943

One concern of modularization is the inspection process. On a typical project, inspectors will come out to the jobsite and inspect floors at a time. Modular construction may require inspectors to visit the off-site warehouse for initial inspections as well as visit the jobsite for final installation inspections.

As seen in Figure 4.4, the cost of stick building increases linearly at a rapid rate as the quantity of units increases. On the other hand, the cost versus quantity of units for modularization and standardization lines are much flatter. Because modularization has a high upfront cost for planning, you can see that with a low quantity of units stick building is more economic.

Where the lines intersect, is the break even point where modularization becomes economic. The cost savings for modularization can be seen in blue. Taking modularization one step further by standardization the additional cost savings are shown in red. With 176 total apartment units on floors three through six, modularization and standardization seem to make sense.

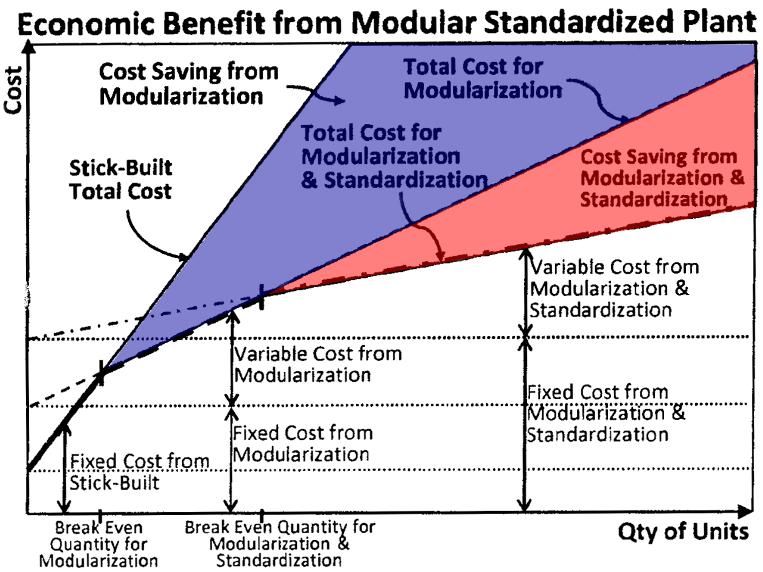


Figure 4.4. Economic Benefit of Standardization
Source: Construction Industry Institute

As seen in Figure 4.5, typical wood framed construction has a height constraint of five stories as regulated by the building code. Modular wood construction allows for high-rise buildings to be built up to eleven stories. Due to the low price of wood construction in comparison to steel and concrete, modular wood construction is bound to have a profound effect on the industry in years to come.

In addition to schedule reduction, on-site productivity is increased as there are less workers and materials on the job-site. This eliminates the stacking of trades allowing for a smoother work flow.

Figure 4.5. High-Rise Modular Wood Construction
Source: http://www.treehugger.com/modular-design/modular-construction-and-cross-laminated-timber-together-last.html

ARCHITECTURAL BREADTH

As you have seen through the research section, modularization is best utilized on standardized or repeatable buildings. This is an issue with the Solaire Wheaton project with its 79 different residential unit layouts as seen in Table 5.1. Although many of these units have only minor differences, there is a major economic benefit of standardization. In order to determine the feasibility of modularization on the Solaire Wheaton, an architectural layout redesign must be conducted. The purpose is to reduce the number of layouts to a more manageable number, resulting in less change over for the fabricators and making modularization more feasible for the project.

Current Apartment Unit Layouts					
Studio		Single Bed		Double Bed	
1	A1.00	1	A3.00	1	B1.00
2	A1.01	2	A3.01	2	B1a.00
3	A2.00	3	A3.02	3	B1b.00
4	A2.01	4	A4.00	4	B2.00
5	A2a.00	5	A5a.00	5	B3.00
6	A2b.00	6	A6.01	6	B3.01
7	A2c.00	7	A6a.00	7	B3.02
8	A2.02	8	A6a.01	8	B3.03
		9	A6a.02	9	B3.04
		10	A6b.00	10	B3.05
		11	A7.00	11	B3.07
		12	A8.00	12	B3a.00
		13	A8.01	13	B3b.00
		14	A8.02	14	B4.00
		15	A8.04	15	B4a.00
		16	A8a.04	16	B6.00
		17	A8b.04	17	B7.00
		18	A8c.04	18	B7.01
		19	A8d.04	19	B7.02
		20	A8.05	20	B8.00
		21	A8.06	21	B9.00
		22	A8.07		
		23	A8.08		
		24	A9.00		
		25	A10.00		
		26	A10.01		
		27	A10.02		
		28	A10.03		
		29	A10a.00		
		30	A10b.00		
		31	A10c.00		
		32	A11.00		
		33	A12.00		
		34	A12.01		
		35	A12.02		
		36	A13.00		
		37	A13.01		
		38	A13a.00		
		39	A13b.00		
		40	A13a.01		
		41	AD1.00		
		42	AD1.01		
		43	AD1a.01		
Total Number of Unit Layouts				72	

Table 5.1. Current Apartment Unit Layouts

After analyzing the typical floor plan, it was noticed that many of the units had the same length and width dimensions. Standardization would require only a few small layout changes within the apartment units. As you can see in Table 5.2, the modified typical floor layout utilizes only 19 different unit types across 44 apartment units.

The distribution of these units can be seen in Figure 5.1. Through this standardization of unit layouts, there is now only two studio layouts, eleven single bedroom layouts, and six double bedroom layouts. This will greatly reduce the change over time for the fabricators.

Adjusted Apartment Unit Layouts					
Studio		Single Bed		Double Bed	
1	A1.00	1	A4.00	1	B1a.00
2	A2.01	2	A6a.01	2	B3.03
		3	A6b.00	3	B3.05
		4	A7.00	4	B4.00
		5	A8.02	5	B6.00
		6	A8.04	6	B7.02
		7	A8.07		
		8	A9.00		
		9	A11.00		
		10	A12.02		
		11	A13a.01		
Total Number of Unit Layouts					19

Table 5.2. Adjusted Apartment Unit Layouts

MODIFIED 6TH FLOOR LAYOUT PLAN

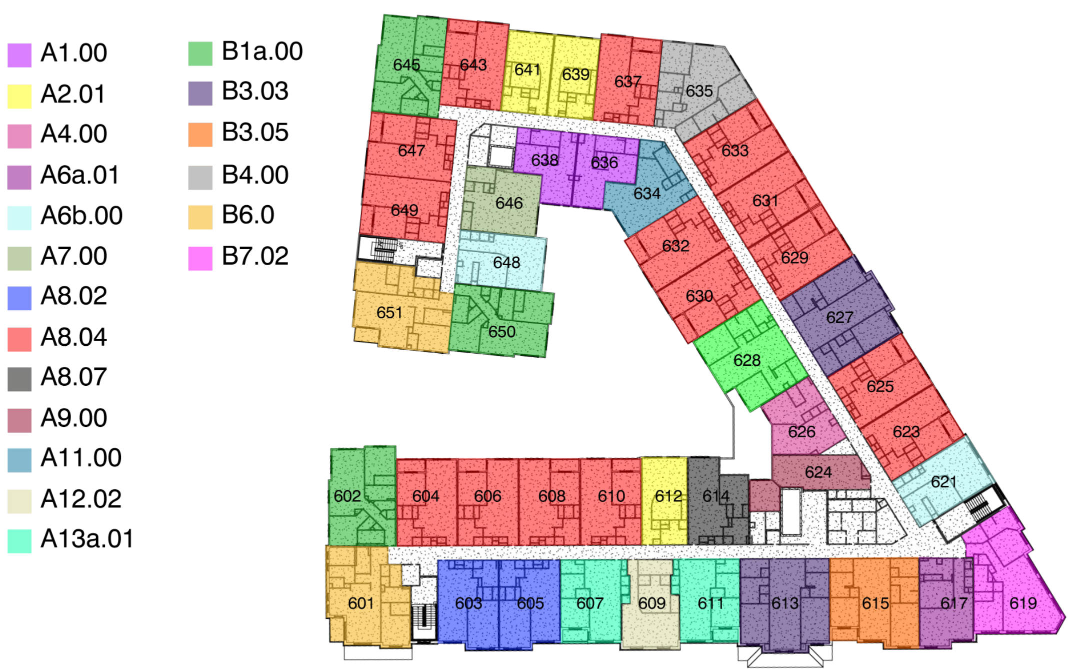


Figure 5.1. Modified Typical Floor Plan

ARCHITECTURAL BREADTH RESULTS

The standardization of apartment units could potentially have a profound effect on the exterior appearance of the building. As seen in Figures 5.2 and 5.4, the east facade of the building is meant to give great curb appeal from Georgia Avenue with its various facade projections. Figures 5.3 and 5.5 illustrate the effects of standardization on this facade. Note differences between corner unit in Figures 5.4 and 5.5 which has been replaced and now incorporates a corner balcony. The other major effect of standardization is the elimination of the smoker balconies on the 6th floor to allow for consistent vertical layouts. Many of the changes are in the interior layouts, while the main concept of the building's exterior design has been preserved.


Figure 5.2. Original Northeast Corner Rendering


Figure 5.3. Modified Northeast Corner Rendering


Figure 5.4. Original Southeast Corner Rendering


Figure 5.5. Modified Southeast Corner Rendering

STRUCTURAL BREADTH

To determine whether construction using modular units is possible for this project, the means of setting the units needs the be further investigated. Although modular units are typically set using a mobile crane, the site restrictions make this an unlikely possibility. The site is accessible on only the north and east sides of the site, making setting units on the southwest corner using a mobile crane unfeasible. The tower crane will still be in place from the structural concrete phase, and will be used for setting the modules. As seen in Figure 6.1 below, the tower crane is placed at the north east corner of the courtyard and has a jib with 180 feet of reach. This crane reach was acceptable with stick built construction methods; however, it is not likely to work for modular construction methods.

It is presumed that due to the large loads associated with modular units, the tower crane and foundation pad will need to increase in size and strength. The following tower crane study will specify a tower crane with an acceptable reach and strength as well as size a mat foundation for the tower crane.

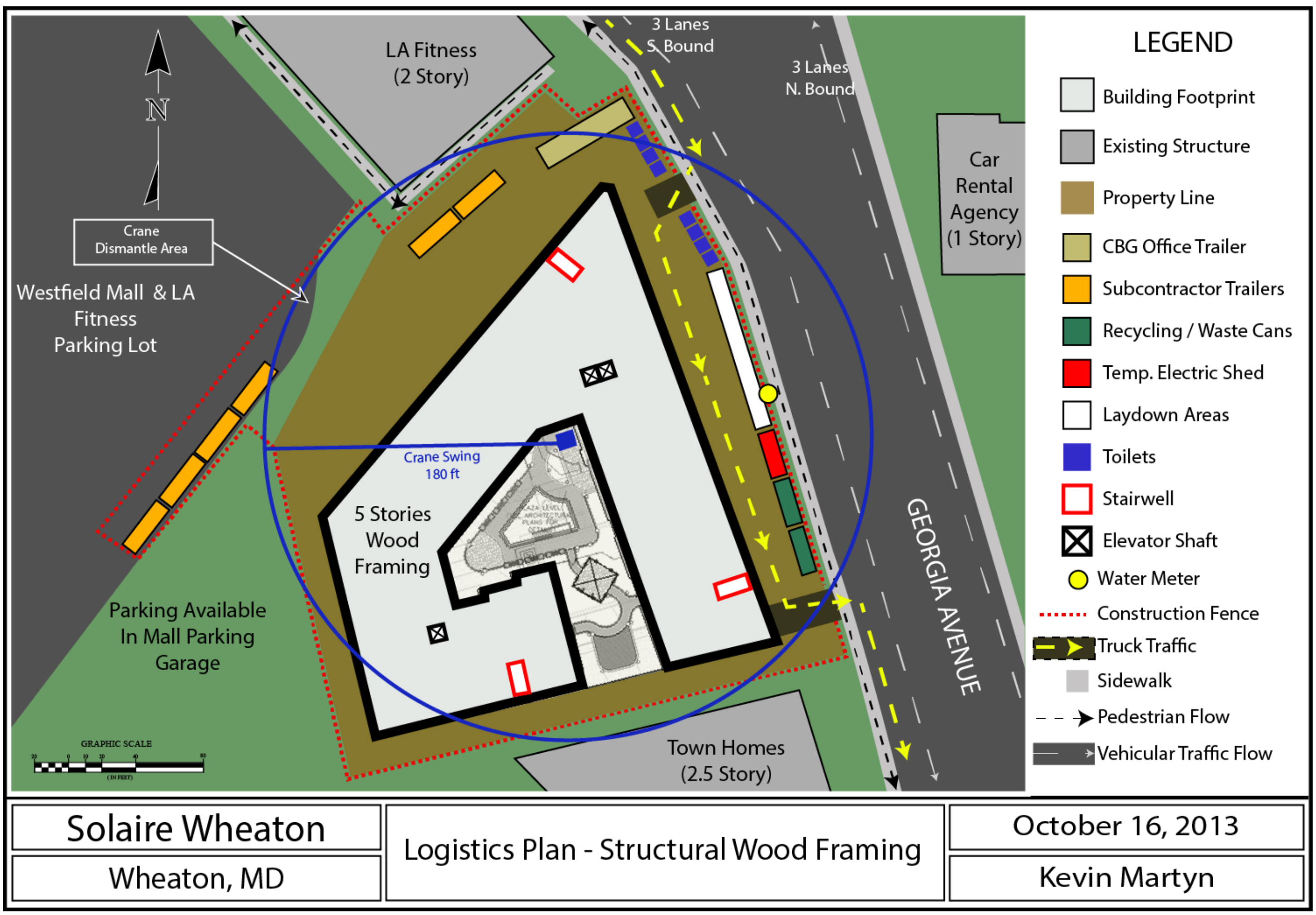


Figure 6.1. Site Logistics Plan

In order to better illustrate the tower crane reach issue as well as determine the required reach, building information modeling was employed. Figure 6.2 shows the current tower crane reach in yellow, and as you can see the jib does not reach the extents of the southwest corner of the building. The majority of the southwest corner apartment unit in not accessible by the crane, and therefore the current crane is not suitable to set the modular units. Using the crane load chart in Appendix #, the shortest crane reach that encompasses the total building footprint is 210 feet. As you can see in Figure 6.3, the 210 foot jib reaches past the southwest corner of the building allowing for modular units to be set.

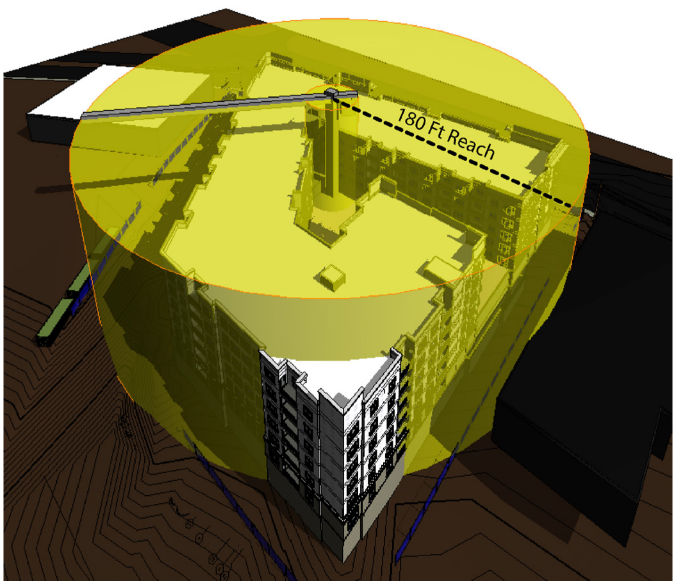


Figure 6.2. Existing Crane with 180 Foot Jib

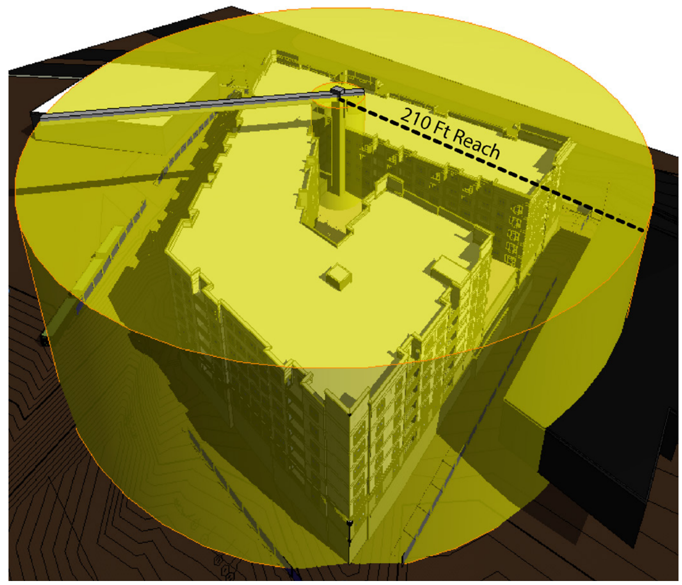


Figure 6.3. Required Crane with 210 Foot Jib

The crane that was chosen for the modular construction methods is the Linden Comansa 21 LC 550, which has a total lifting capacity of 39,670 lbs. The load chart for this crane can be found in Appendix #, and was used to ensure that the crane has the necessary capacity to pick the units. As seen in the load chart, at 210 feet the Linden Comansa 550 tower crane has a lifting capacity of 14,770 lbs.

To estimate the weight of the modules, the density of wood is assumed to be approximately 30 pounds per cubic foot (pcf). The typical module volume is 2730 cubic feet. A conservative assumption is that the wood framing occupies 5% of the module. This conservative assumption will adjust for the MEP and enclosure items as well as the concrete balcony slabs. The tower crane load chart is assumed to have built in factors of safety so these can be ignored. Using these assumptions, the weight of the module is estimated to be 4,095 lbs which is just under the lifting capacity of 14,770 lbs.

The final piece of this tower crane study is to size the mat foundation required to stabilize the crane during operation as well as during down time. Figure 6.4 illustrates the four major reaction forces at the base of the crane, including: overturning moment, vertical load, lateral or horizontal load, and slewing moment or twisting.

Table 6.1 shows the estimated forces for this particular tower crane which were taken from the Linden Comansa reaction forces table which can be found in Appendix B. These forces are the basis of the calculations required to size the mat foundation. Note that the zero slewing moment when the crane is out of operation is because the crane is weather vaned, or allowed to swing freely. The following pages document the calculations used to determine the dimensions of the mat, size the reinforcement, and check resistance to overturning and slewing moments as well as one-way and punching shear.

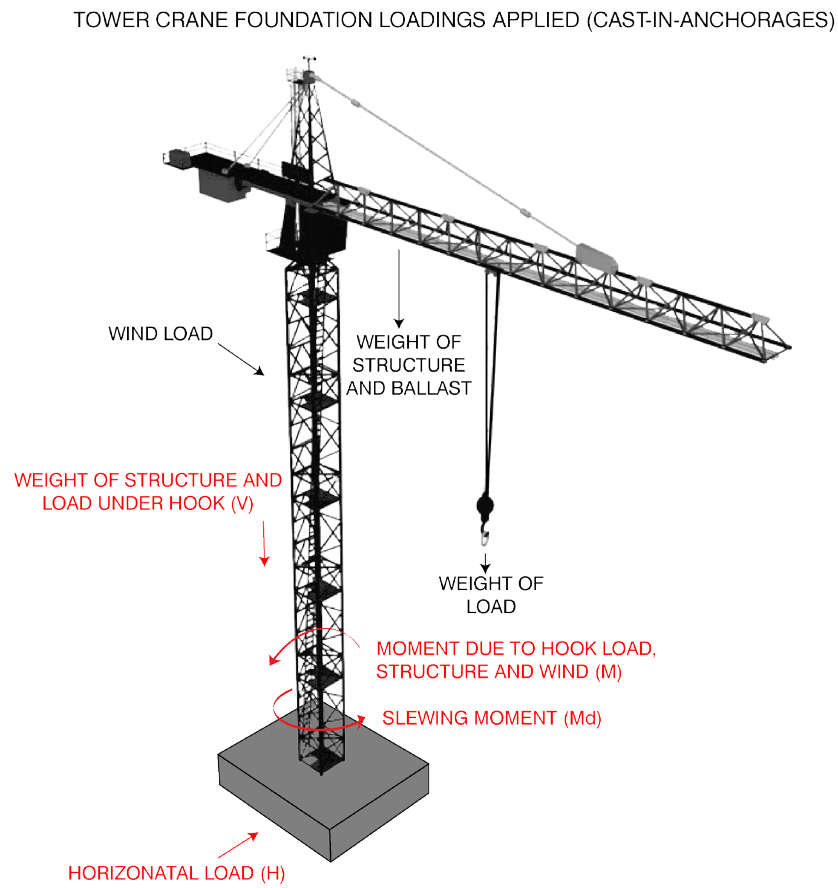


Figure 6.4. Tower Crane Reaction Forces

Tower Crane Foundation Reaction Forces			
Load	**Units**	**In-Operation**	**Out-of-Operation**
Overturning Moment, M	ft-kips	3098	3480
Vertical Load, V	kips	268	253
Horizontal Load, H	kips	7	21
Slewing Moment, Md	ft-kips	564	0

Table 6.1. Tower Crane Reaction Forces

TOWER CRANE MAT DESIGN:

CRANE CONFIGURATION:

Model: LINDEN COMANSA 21 LC 550

Hook Height: 126 ft — Crane Mast Base Plan Dimension, Bc = 6.5 ft

Jib Reach: 210 ft

BASE FORCES AT TOP OF MAT:

	M		H		V		Md	
In Operation	3098	ft-kips	7	kips	268	kips	564	ft-kips
Out of Operation	3480	ft-kips	21	kips	253	kips	-	ft-kips
GOVERNING LOAD CONDITION:	3480	ft-kips	21	kips	268	kips	564	ft-kips

ALLOWABLE SOIL BEARING CAPACITY= 6000 psf — **SOIL TYPE:** Clayey Sand

MAT MATERIALS:

f'c= 3500 psi — **Fy=** 60 ksi — ASTM A615 Grade 60

Min. Cover 3.5 in

MAT SIZE ASSUMPTIONS:

Plan Size B x L — **B=** 22 ft — **L=** 22 ft

Thickness — **D=** 3.5 ft

Mat Dead Load — **Wm=** 254 kips (150 pcf x L x B x D)

Overturning Moment — **Mot=** M+(HxDf) = 3480(21*3.5)

Mot= 3554 ft-kips

Loading Eccentricity — **e=** Mot/(V+Wm)>B/6 = 2779/(268+254)>22/6

e= 7 ft >B/6 3.67 => OK

Max Soil Stress — **fbr max=** (2x(V+Wm)/(3xLx(B/2-e))) = (2*(268+254)/(3*22*(22/2-7))

fbr max= 3772 psf < Allowable Soil Bearing Capacity =>OK

COMPUTE SOIL STRESS @ FACE OF MAST

Edge Distance

Ed= .5(B-Bc) = .5(22-6.5) — **Lfbr =** 3(B/2-e) = 3(22/2-7)

Ed= 7.75 ft — **Lfbr =** 12.58 ft

L2 Ed/2 = 7.75/2 — **L1=** 2/3(B/2 - Bc/2) = 2/3(22/2 - 6.5/2)

L2 3.88 — **L1=** 5.17 ft

fbrmast= fbrmax(Lfbr-B/2+Bc/2)/Lfbr = 3772(12.58-22/2+6.5/2)/12.58

fbrmast= 1448.70 psf

RESISTANCE TO OVERTURNING

Resisting Moments — Mr= (Wm+V)B/2 = (254+268)22/2

Mr= 5743.1 ft-kips

Factor of Safety for Overturing (FSot)= Mr/Mot >= 1.5 = 5743.1/3554

FSot= 1.62

FSot= 1.62 => OK for Overturning

DESIGN REINFORCEMENT FOR TOWER CRANE MAT:

COMPUTE BENDING MOMENT FOR BOTTOM REBAR:

V1u= (fbrmax-fbrmast)(Ed/2)1.6 x L
V1u= ((2926-1163)(7.75/2)1.6*22)/1000
V1u= 316.97 kips
M1u= V1u x L1 = 316.97*5.17
M1u= 1637.66 ft-kips

V2u= (fbrmast) x Ed x 1.6 x L
V2u= (1163*7.75*1.6*22)/1000
V2u= 395.2 kips
M2u= V2u x L2 = 395.2*3.88
M2u= 1531.42 ft-kips

Total Mu= M1u + M2u = 1637.66 + 1531.42
Total Mu= 3169.0761 ft-kips

TRY **See Rebar Calculations**

No. 11's Spaced at	12 in. oc	As=	31.2 in.^2	d=	37.80 in.
No. 10's Spaced at	12 in. oc	As=	25.4 in.^2	d=	37.87 in.
No. 9's Spaced at	12 in. oc	As=	20.0 in.^2	d=	37.94 in.
No. 8's Spaced at	12 in. oc	As=	15.8 in.^2	d=	38.00 in.
No. 7's Spaced at	12 in. oc	As=	12.0 in.^2	d=	38.06 in.

TRIAL SECTION No. 8 12 in. oc As= 20.0 in.^2 d= 37.94 in.

ΦMn= 0.9(AsFy(d-AsFy/(1.7f'cB)))>=Increased Mu
ΦMn= (0.9(20.0*60*(37.94-(20.0*60/(1.7*3500/1000*22*12))))/12)>=Increased Mu
ΦMn= 3345.8452 ft-kips
Total Mu= 3169.0761 ft-kips

=> OK
USE: #9's @12" O.C. IN BOTTOM MAT

COMPUTE BENDING MOMENT FOR TOP REBAR:

Vu= D*0.150kcf*Ed*L*1.6 = 3.5*0.150kcf*7.75*22*1.6
Vu= 143.22 kips
Mu= Vu*Ed/2 = 143.22*7.75/2
Mu= 554.98 ft-kips

TRY No. 9's Spaced at	12 in. oc	As=	20.0 in.^2	d=	37.94 in.
No. 8's Spaced at	12 in. oc	As=	15.8 in.^2	d=	38.00 in.
No. 7's Spaced at	12 in. oc	As=	12.0 in.^2	d=	38.06 in.

TRIAL SECTION No. 7 12 in. oc As= 20.0 in.^2 d= 37.94 in.

ΦMn= 0.9(AsFy(d-AsFy/(1.7f'cB)))>=Increased Mu
ΦMn= (0.9(20.0*60*(37.94-(20.0*60/(1.7*3500/1000*22*12))))/12)>=Increased Mu
ΦMn= 3345.8452 ft-kips
Total Mu= 554.98 ft-kips

=> OK
USE: #9's @12" O.C. IN TOP MAT

COMPUTE MINIMUM TEMPERATURE & SHRINKAGE REINFORCEMENT

Asmin= 0.0018 x B x D = 0.0018*22*12*3.5*12
Asmin= 19.9584 in.^2

As (top) + As (bot)= 40.0 in.^2 >Asmin => OK

REBAR CALCULATIONS

D= 42 in. Min. Cvr. = 3.5 in.

Bar	Spacing	As(bar)	Ftg. L	Tot. As As*(Ftg. L -2)	Diam. (bar)	Depth (d) D-Min.Cvr.-Diam/2
No. 11's	12 in. oc	1.56	22	31.2	1.410	37.80
No. 10's	12 in. oc	1.27	22	25.4	1.270	37.87
No. 9's	12 in. oc	1.00	22	20.0	1.128	37.94
No. 8's	12 in. oc	0.79	22	15.8	1.000	38.00
No. 7's	12 in. oc	0.60	22	12.0	0.875	38.06
No. 6's	12 in. oc	0.44	22	8.80	0.750	38.13
No. 5's	12 in. oc	0.31	22	6.20	0.625	38.19
No. 4's	12 in. oc	0.20	22	4.00	0.500	38.25

CHECK RESISTANCE TO SLEWING MOMENT:

Resisting force is assumed to be a triangular force distribution on all four sides as developed by passive soils

Soil Unit Weight:	γ= 125 pcf				
Friction Angle	Φ= 35 degrees				
	Kp= tan^2(45+Φ/2)				
	Kp= tan^2(45+35/2)				
	Kp= 3.69				
Max. Allow. Resisting Pressure	Qr= 0.5 x Kp x γ x Df^2				
	Qr= (0.5*3.69*125*3.5^2)/1000				
	Qr= 2.83 kips/LF				
Resistance Along B Side of Footing	Mrb= Qr(B/2)	Moment Arm	Br= B/3		
	Mrb= 2.83(22/2)		Br= 22/3		
	Mrb= 31.08 kips		Br= 7.33 ft		
Resistance Along L Side of Footing	Mrl= Qr(L/2)	Moment Arm	Lr= L/3		
	Mrl= 2.83(22/2)		Lr= 22/3		
	Mrl= 31.08 kips		Lr= 7.33 ft		
Resisting Moments					
	ΣMr= 2((Mrb x Br) + (Mrl x Lr))				
	ΣMr= 2((31.08*7.33) + (31.08*7.33))				
	ΣMr= 911.58 kips				
	FSsm= ΣMr/Md >=1.5				
	FSsm= 911.58/564				
	FSsm= 1.62 => OK for Slewing Moment				

CHECK SHEAR IN THE MAT SLAB:

CHECK ONE WAY SHEAR IN THE MAT:

Shear Area

Av= L x (D-6)

Av= 22*12*((3.5*12)-6)

Av= 9504 in^2

Vu= V1u + V2u

Vu= 316.97 + 395.2

Vu= 712.17 kips

fvu= Vu/Av

fvu= 712.17/9504*1000

fvu= 74.93 psi

ΦVu= 0.85(2)(f'c^0.5)

ΦVu= 0.85*2*(3500^0.5)

ΦVu= 100.57 psi >fvu => OK in Shear

CHECK PUNCHING SHEAR AT ERECTION:

f'c= 2000 psi MINIMUM

Critical Section

Bo= 4 sides (Bc + d)

Punching shear control for this temporary condition

Bo= 4 sides (6.5 + 37.94)

Bo= 463.76 in.

Vu= 1.6V

Vu= 1.6*268

Vu= 428.8 kips

ΦVc= 0.85(4)(f'c^0.5)(Bo)(d)

ΦVc= (0.85*4*(3500^0.5)*463.76*37.94)/1000

ΦVc= 3539 kips >Vu => OK for Punching Shear at Erection

STRUCTURAL BREADTH RESULTS

Figure 6.5 shows a detail of the mat foundation required for the Linden Comansa 21 LC 550 tower crane. As you can see, the preceding calculations yielded a square 22 foot long and 3 1/2 foot deep mat foundation. These dimensions are a result of the allowable soil bearing capacity of 6000 pounds per square foot (psf), specified in the geotechnical report. The mat slab is placed using 3500 psi concrete, and the reinforcement bars are #9's at 12" on center yielding 22 in each direction in the top and bottom mats.

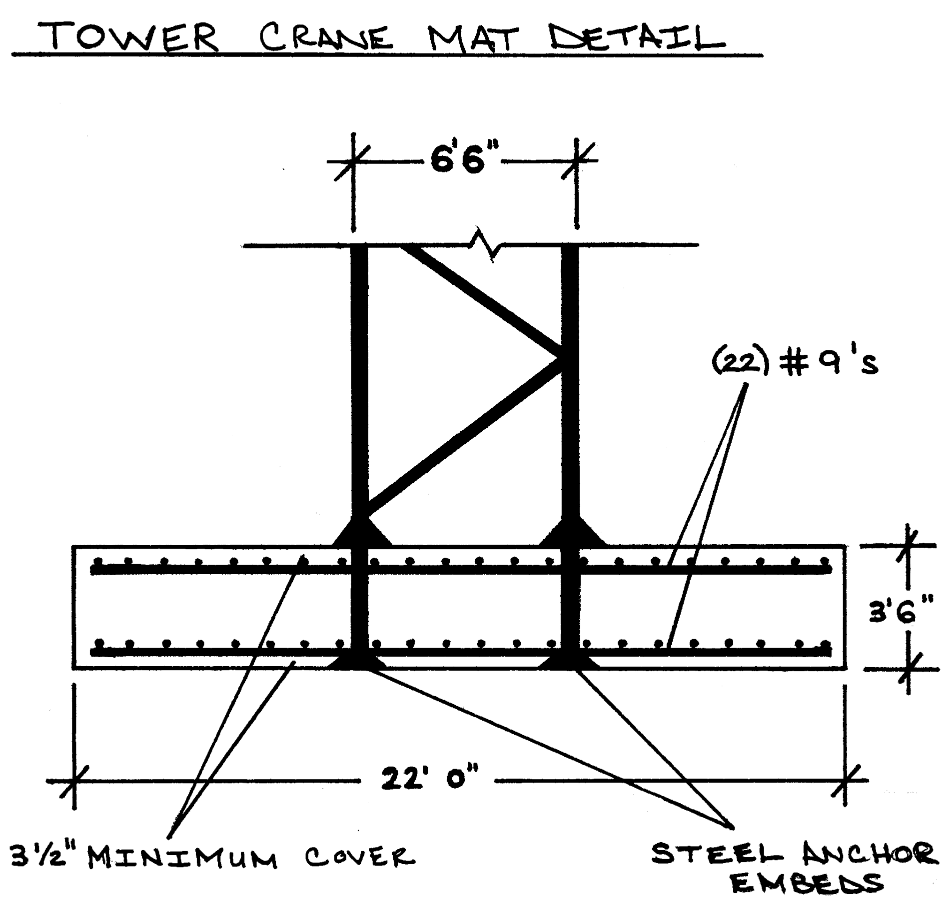


Figure 6.5. Tower Crane Mat Detail

The final part of the study to size the appropriate tower crane for modularization brings us to placement within the current foundation plan. The new tower crane will take the same position as the actual one in the northeast corner of the courtyard. As you can see in Figure 6.6, the tower crane mat foundation intersects with a spread column footer at column line G8. The solution to this is to integrate column G8 with the tower crane mat foundation. This may require further analysis and more complicated calculations as the foundation mat would need to be designed considering the building load supported by column G8.

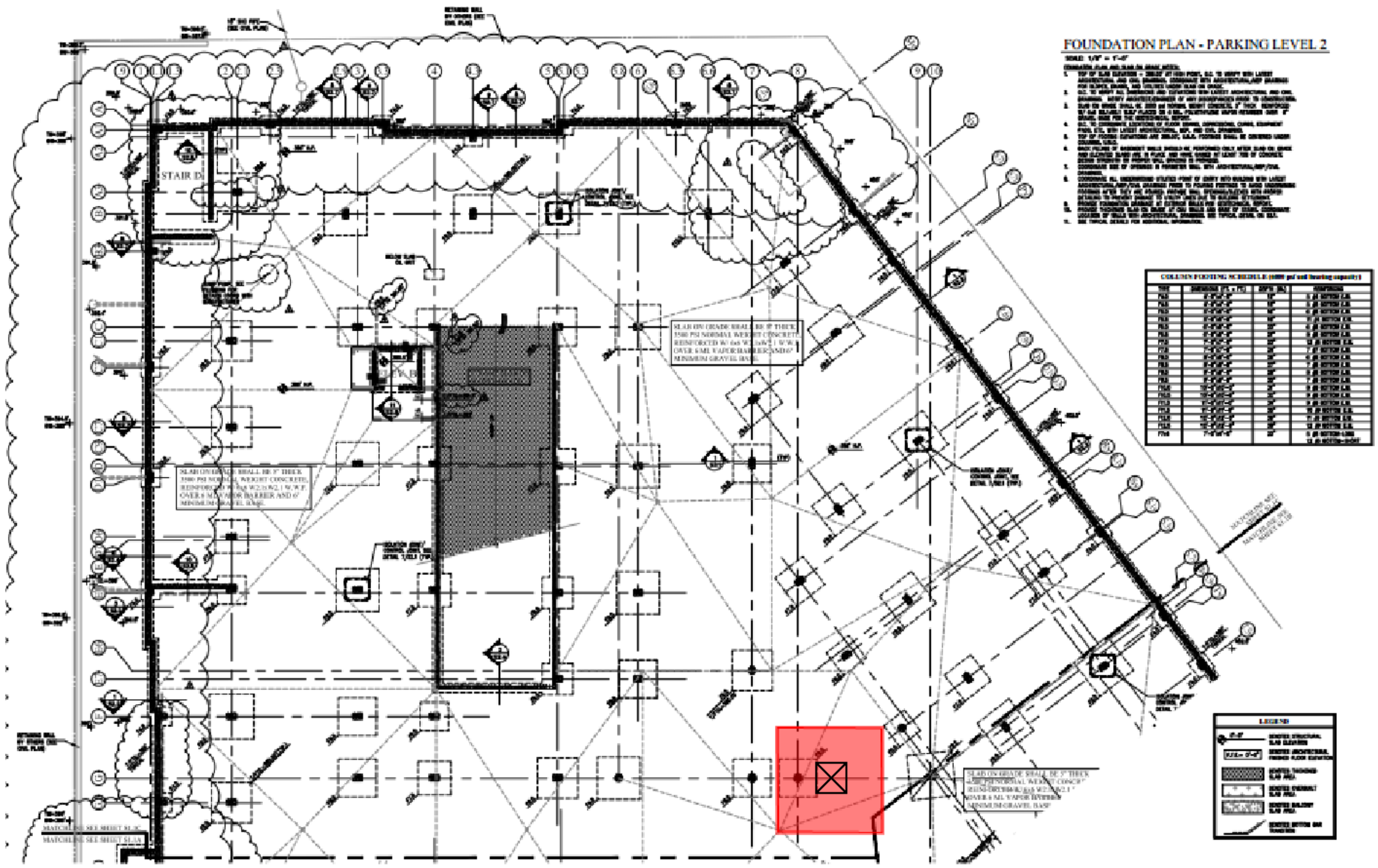


Figure 6.6. Tower Crane Mat Foundation Placement

POTENTIAL SOLUTION

The lifting capacity of the tower crane has limited the modules to half the unit length. For this reason, each unit will have double the amount of modules. Studio and single bedroom apartments which may typically consist of two 34’ long modules are now limited to four 17’ long modules. The same holds true for the double bedroom layouts which have increased from three modules to six. In Figure 4.6 below, you can see unit 8.04 modeled in Autodesk Revit.

Figure 4.6. Solaire Wheaton Modular Units

Figure 4.7 shows the an exploded axonometric of the 3D Revit model. As you can see, the scope of the model includes: floor, wall, and ceiling assemblies as well as MEP rough-in and aluminum window installation. The MEP rough-in and window installation processes caused significant delays in the critical path on the project. Moving these activities off-site and building them in advance will eliminate these delays in the on-site project schedule.

The MEP distribution systems will be connected upon setting the units. The structural connections are assumed to be by steel straps or gusset plates.

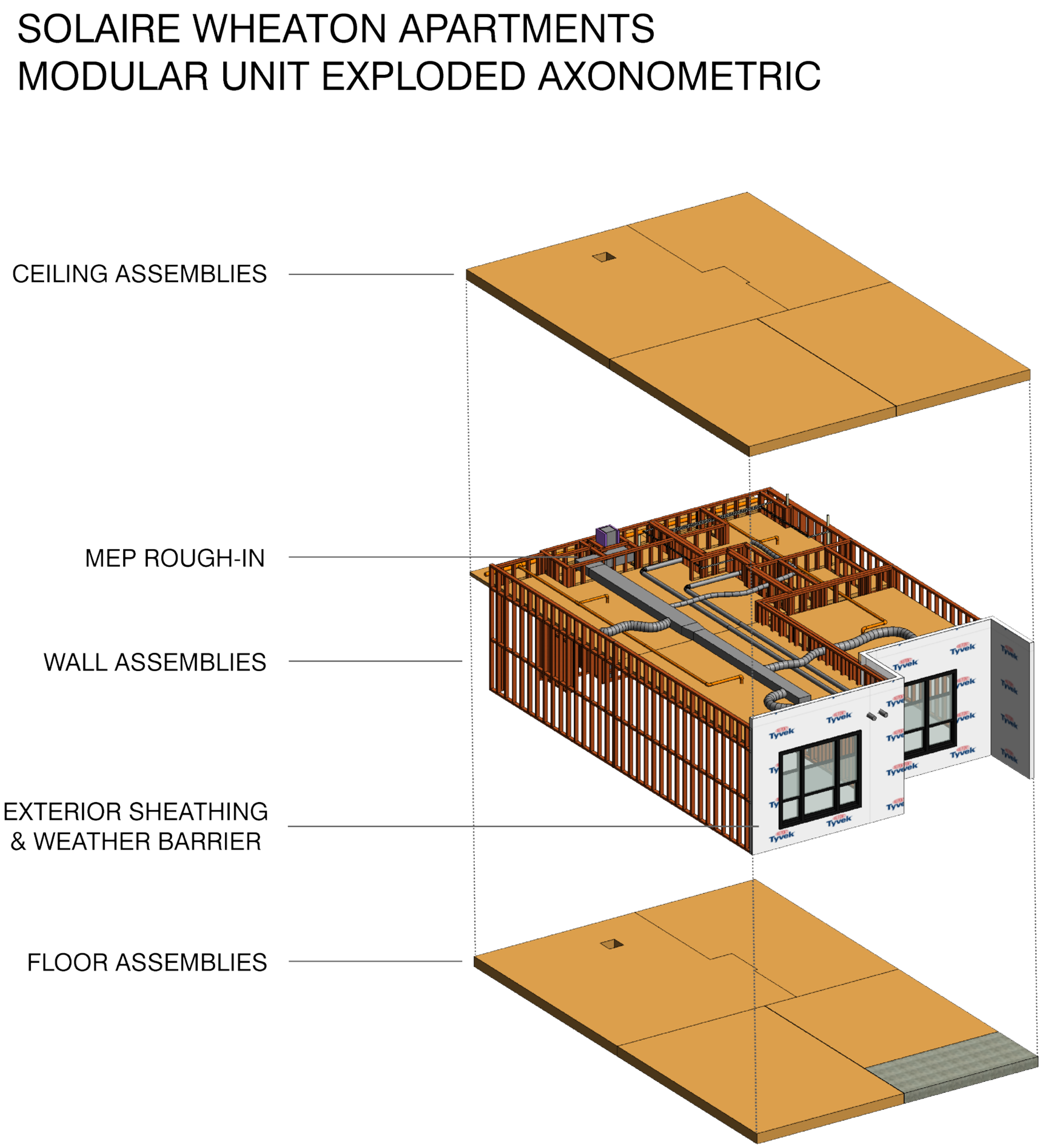


Figure 4.7. Modular Unit Exploded Axonometric

RESTRICTIONS AND OPPORTUNITIES

One of the major restrictions associated with modularization is in transportation of the modules. Appendix C, documents the Maryland hauling permit load requirements. As you can see in Table 4.1, after investigating the size of the modules, there are no major permit load requirements necessary for the Solaire Wheaton project. The only compliance requirement to be concerned with is the module width. As some of the modules can be upwards of 13 feet wide, wide load signs will be required and beltway hour travel restrictions will need to be complied with.

Hauling Permit Load Compliance			
Estimated Max. Dimensions		Compliance Requirements	
Width	12' 9"	12-13 Feet	Wide Load Signs Required Beltway Hours - Travel restrictions apply where applicable
Height	10' 7 7/8"	< 13' 6"	Legal Limit - No special conditions apply
Length	17' 0"	< 55 Feet	No Special Notes or Conditions

Table 4.1. Hauling Permit Load Compliance

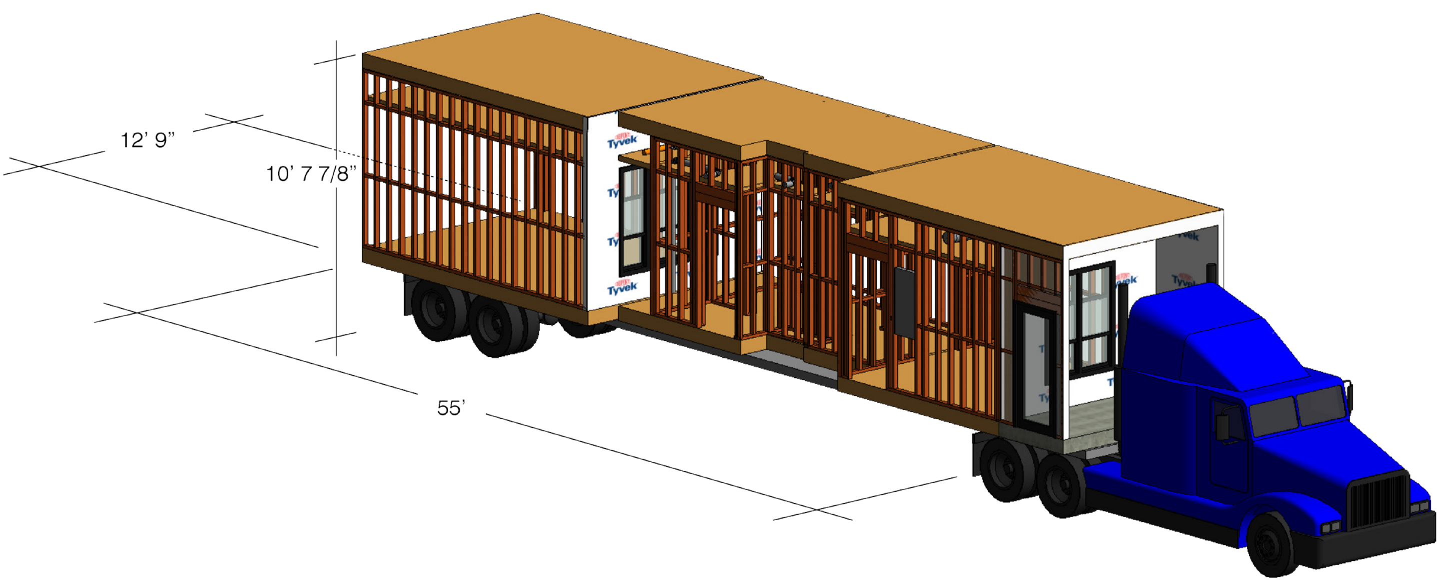


Figure 4.8. Modular Unit Transportation Method

On the other hand, one of the major opportunities with modular construction in minimizing the waste that must be removed from a jobsite. All of the packaging and wasted materials never make their way to the jobsite reducing congestions of the work space, increasing productivity.

There is also the opportunity to reduce the amount of movements to the jobsite. As seen in Table 4.2, modular construction methods on the Solaire Wheaton project can eliminate over 6,000 movements to the jobsite. If you assume that workers carpool in threes, this can result in over 2,000 car movements avoided. This will also lessen the burden on public transportation such as buses and the metro. Although this may seem hypocritical because the workers will still have to travel to the off-site warehouse, contractors can utilize local workers at the warehouse who have minimal travel. The reduction in on-site labor will decrease the congestion in the workspace and increase productivity.

Estimated Number of Jobsite Movements Avoided					
Contractor	Average Wkrs/Day	Duration (Months)	Working Days/Month	Total Working Days	Total Workers to Jobsite
				Duration*Working Days/Month	Wkrs/Day*Total Working Days
Wood Framing	30	3.66	21	77	2306
Mechanical	8	5.5	21	116	924
Plumbing	10	5.5	21	116	1155
Electrical	15	5.5	21	116	1733
CM	1	6.5	21	137	137
Estimated Movements to Jobsite Avoided:					**6254**
Car Movements Avoided (Assume 3 workers/ Car):					2085

Table 4.2. Estimated Number of Jobsite Movements Avoided

The most important opportunity that modularization implementation presents is the reduction of hours of worker fall exposure. Wood framing carpenters are exposed to falls during nearly all tasks that they perform. These include framing exterior walls, setting floor trusses, working on the leading edge of a floor deck, and installing sheathing and tyvek on the outside of the building. In order to estimate what percentage of time workers are exposed to falls it is important to look into each task. As you can see in Table 4.3 each task in yellow is identified as potential fall exposure tasks. Each task is then analyzed on the percentage of the total time that workers are exposed to a fall while performing this task. This calculation yields a result of fall exposure during 44% of man hours.

Wood Framing Worker Fall Exposure Percentage			
Tasks	**Task Duration (% of Total)**	**Fall Exposure During Task**	**Total Fall Exposure (% of Total)**
Frame Exterior Walls	20%	30%	6%
Frame Interior Walls	35%	0%	0%
Set Floor Trusses	25%	90%	23%
Install Floor Deck	5%	40%	2%
Sheath Exterior Wall	10%	90%	9%
Install Tyvek Building Wrap	5%	90%	5%
Total	**100%**		**44%**

Table 4.3. Man Hour Fall Exposure Percentage

As you can see in Table 4.4 on the next page, the estimated man hours of fall exposure on the project totals nearly 11,000. This is a product of superintendent daily report data and the estimate that wood framing carpenters are exposed to falls during 44% of the working day. This opportunity of modularization will reduce potential injuries and fatalities as well as reduce the risk assumed by a construction manager with a contractor controlled insurance program. This alone should be a strong enough argument for the increased implementation of modularization in the industry.

Estimated Man Hours of Fall Exposure (Wood Framers)						
Day	Month (2013)					
	Jan	Feb	Mar	Apr	May	Total
1		4	34	44	9	
2		0	34	45	9	
3				45	9	
4		6	34	44	9	
5		6	34	43		
6		17	34	21	9	
7		17	34		9	
8		7	34	45	9	
9		17	34	45	9	
10				49	9	
11		16	34	38	9	
12		17	34	5		
13		34	34	40	9	
14		33	34		9	
15		33	34	40	9	
16		33	34	45	9	
17				45	9	
18		34	44	45	9	
19		35	44	45		
20		47	44	45	9	
21		49	44		9	
22		47	44	45	9	
23		10	44	45	9	
24				45	9	
25		56	44	45	9	
26		51	44	45		
27		51	44	45	9	
28		52	44		9	
29			44	45	9	
30	3		44	45	9	
31	4			45	9	
Total Man Days	7	672	1,004	1,134	243	3,060
Total Man Hours	56	5,376	8,032	9,072	1,944	24,480
Estimated Man Hours of Fall Exposure (44% of Total Man hours)						**10,771**

Table 4.4. Estimated Man Hours of Fall Exposure

EXECUTION PLAN & STRATEGY

The first step of the execution plan is to find warehouse space in which the modules can be built. Ideally this space should be close to the jobsite minimizing travel distance. Warehouse space is currently available in Hyattesville, Maryland and includes 12,144 square feet with a 24 foot ceiling height making the space ideal for off site modular prefabrication. The basic layout of the space can be seen in Figure 4.9. As you can see, the space has an open layout with minimal interior columns making it a great space to build modules in an assembly line fashion.

This space is renting at $5.75/SF/year. At this rate, the warehouse will cost $69,828 per year or $5,819 per month. Estimating that the space will need to be rented for a total of 15 months, brings us to a total cost of $87,285. This is not a major cost to be incurred on a project with a $31 million guaranteed maximum price contract when compared to the cost reduction associated with a shorter schedule duration.

Figure 4.9. Warehouse Layout

As you can see in Figure 4.10, the warehouse space is 12.4 miles from the jobsite with a travel time of approximately 24 minutes. As the map illustrates, the route does include a short distance on the Beltway (I-495) so the Maryland hauling travel hour restrictions mentioned earlier will need to be complied with.

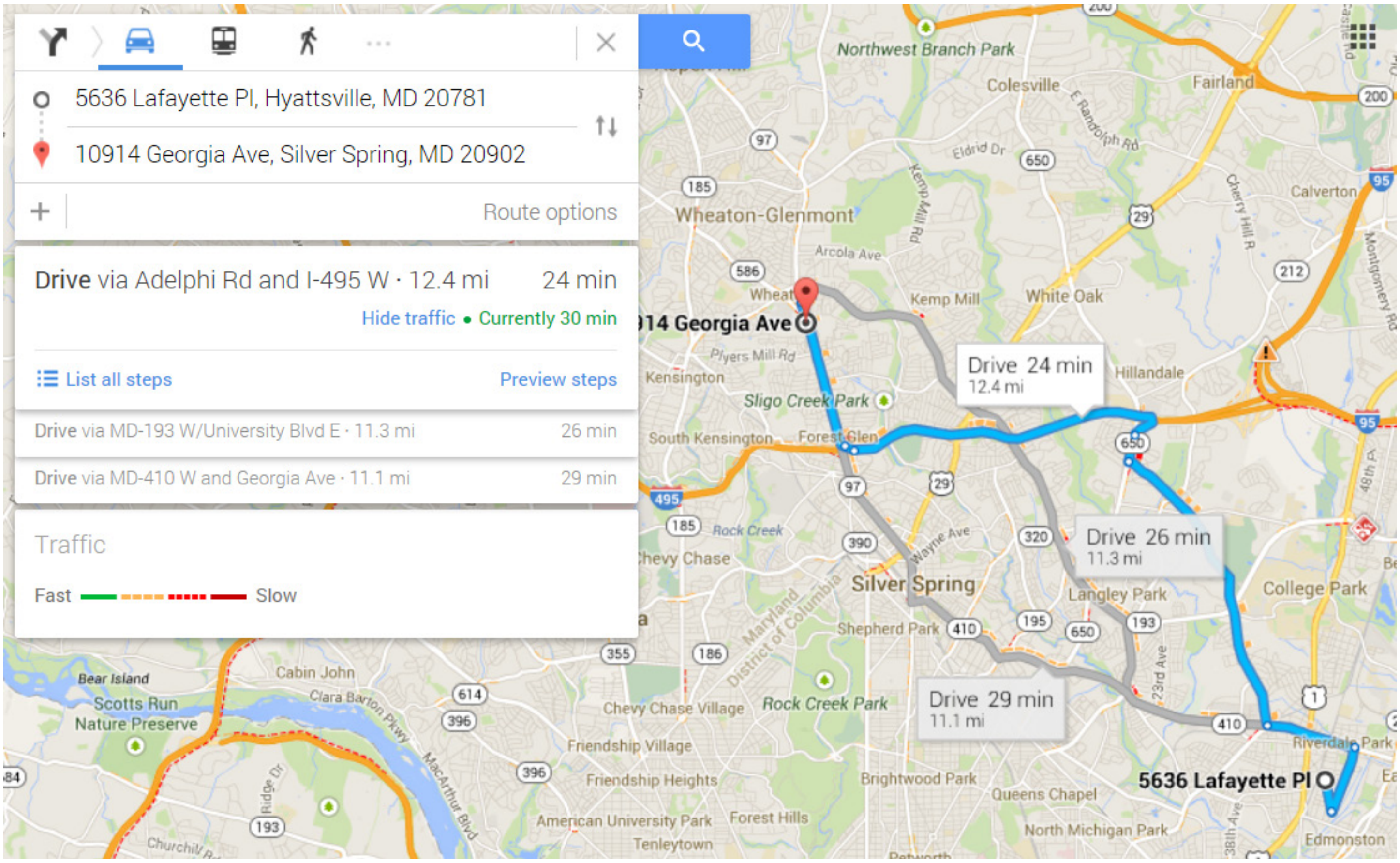


Figure 4.10. Warehouse Directions to Jobsite

COST ANALYSIS

There are many considerations when looking at the cost implications of modularization as seen in Figure 4.5.

As we have seen, the off-site fabrication space is a major cost incurred at $87,285. The will also be an added cost for a mobile crane to load the modules on trucks at the off-site fabrication space. In Appendix D, you will find trucking costs from the American Transportation Research Institute. Rotating 2 trucks at $68.21 per hour for a truck, the total transportation costs come to $68,755. To resist damage during transportation, there will be an added structural material for bracing at $46,440.

The major cost reductions include reduced tower crane fees, labor productivity increases, and on-site general conditions reductions. The revised general conditions estimate for the two month schedule reduction can be found in Appendix E. It is important to note that the owner can collect about $638,800 in rental fee revenue with the 2 month reduction in substantial completion.

Considering all of these costs, modularization results in over $175,000 in cost reduction.

Modularization Cost Analysis		
Description	**Cost Increase**	**Cost Reduction**
Warehouse Cost	**$87,285.00**	
Off-site General Conditions (6 months) Assume $33,000/month	**$200,000.00**	
Mobile Crane for Warehouse ($120/hour) $120/hour * 8 hours/ day = $960/day $960/day * 21 days/month = $20,160/month $20,160/month * 3 months = $60,480	**$60,480.00**	
Transportation Cost $68.21/hour/truck * 2 trucks * 8 hrs/day = $1091.36/day $1091.36/day * 21 days/month * 3 months = $68,755.68	**$68,755.68**	
Material Increase (Structural Bracing) Total Framing Contract = $2,340,000 Less 30% Markup = $1,638,000 Material Cost (60%) = $928,800 Structural Increase (5%) = $46,440	**$46,440.00**	
Reduced Crane Fees (1 month)		**$15,000.00**
Labor Productivity Increases Assume 15% for Off-site Fabrication		**$461,503.00**
On-site General Conditions (2 months)		**$162,020.00**
Total Cost Increases	**$462,960.68**	
Total Cost Decreases		**$638,523.00**
Total Cost Implication	**-$175,562.32**	

Table 4.5. Modularization Cost Analysis

SCHEDULE ANALYSIS

The major selling point of modular construction is the 30%-50% reduction of schedule. The calculations on the following page provide the estimated duration for the construction and setting of modules.

As you will see there is an extremely long duration for the construction of modules due to the sheer number of modules and the production rate. It is not better production rates that allows modular construction to result in schedule reduction, but rather the simultaneous sequencing. Using an article called, *Lean Transformation in a Modular Building Company*, the estimated production rate for the Solaire Wheaton project is 1.5 modules per day. Because of this increase in overall time of activities, this will push the construction of modules back into the design phase. For this reason, the design will need to be fast-tracked to release module design documents in enough time for module construction to start.

As noted before, modules will be transported to the site by truck in threes. It is estimated that the crews can set upwards of 11 modules per day. This results in 3 months of setting modules, which reduces on-site construction by 4 months as seen in the modularization schedule on page 59.

MODULE CONSTRUCTION SCHEDULE CALCULATIONS

$$1.5\,\frac{Modules}{Day} \times \,6\,\frac{Days}{Week} \;=\; \sim 9\,\frac{Modules}{Week}$$

$$200\,\frac{Modules}{Floor} \div \,9\,\frac{Modules}{Week} \;=\; \sim 22.2\,\frac{Weeks}{Floor}$$

$$22.2\,\frac{Weeks}{Floor} \times 4\,Floors = 88\,Weeks = 1\,Year\;3\,Months$$

MODULE TRANSPORTATION AND SETTING

$$1.38\,\frac{Modules}{Hour} \times \,8\,\frac{Hours}{Day} \;=\; \sim 11\,\frac{Modules}{Day}$$

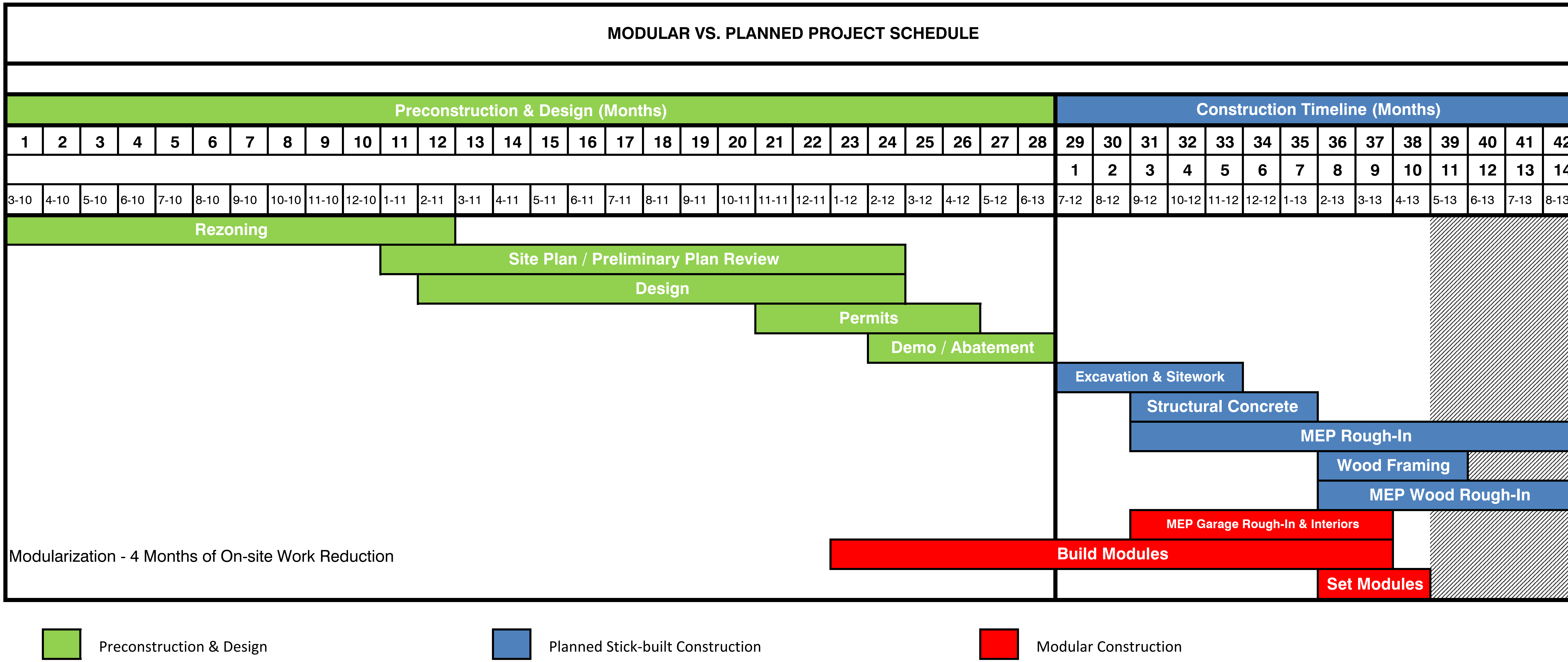
$$11\,\frac{Modules}{Day} \times \,6\,\frac{Days}{Week} \;=\; \sim 67\,\frac{Modules}{Week}$$

$$200\,\frac{Modules}{Floor} \div \,67\,\frac{Modules}{Week} \;=\; \sim 3\,\frac{Weeks}{Floor}$$

$$3\,\frac{Weeks}{Floor} \times 4\,Floors = 12\,Weeks = 3\,Months$$

OVERALL ON-SITE SCHEDULE EFFECTS

$$\frac{6.5\,Months\;(Stick - Built) - \;3\,Months\;(Modular)}{6.5\,Months\;(Stick - Built)} = 52\%\;Reduction\;in\;Schedule$$



MODULAR VS. PLANNED PROJECT SCHEDULE
Preconstruction & Design (Months)
Construction Timeline (Months)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
1 2 3 4 5 6 7 8 9 10 11 12 13 14
3-10 4-10 5-10 6-10 7-10 8-10 9-10 10-10 11-10 12-10 1-11 2-11 3-11 4-11 5-11 6-11 7-11 8-11 9-11 10-11 11-11 12-11 1-12 2-12 3-12 4-12 5-12 6-13 7-12 8-12 9-12 10-12 11-12 12-12 1-13 2-13 3-13 4-13 5-13 6-13 7-13 8-13
Rezoning
Site Plan / Preliminary Plan Review
Design
Permits
Demo / Abatement
Excavation & Sitework
Structural Concrete
MEP Rough-In
Wood Framing
MEP Wood Rough-In
MEP Garage Rough-In & Interiors
Modularization - 4 Months of On-site Work Reduction
Build Modules
Set Modules
Preconstruction & Design
Planned Stick-built Construction
Modular Construction

MAE REQUIREMENTS

Modularization was a concept that was first introduced in the AE 570 course, better known as Production Management in Construction. Within the class, case studies were researched and projects were designed to integrate and teach modularization concepts. This class provided the basis for the analysis which was coupled with further research into its implementation on construction projects such as the Solaire Wheaton project.

RESULTS / CONCLUSION

The shift of work to an off-site location through modularization allows for the simultaneous sequencing of work. This approach will allow the wood framed structure to be built during site improvements, and concrete foundation and superstructure work. As the structural concrete phase wraps up, the modules can begin to be transported to site and set in place by the tower crane. Modularization and standardization on the Solaire Wheaton project has the following advantages and disadvantages:

Advantages
- 4 months reduction of on-site work
- $138,563 in cost reduction
- 6254 jobsite movements displaced
- 10,771 man hours of fall exposure avoided
- Minimize on-site waste
- Increased quality

Disadvantages
- Fast tracked design in order to construct modules
- Increased planning and trade coordination

As this analysis proves, modularization is not an after thought. This construction method needs to be employed at the very conception of the project to utilize standardization and fast-tracked design. Although there is increased planning and coordination involved with modularization implementation, there are many benefits. If the project team is on board from the beginning, modularization can reduce schedule, cost, jobsite movements, fall exposure, and on site while increasing quality.

CONSTRUCTION STUDY 4 – SIPS FOR INTERIOR FINISHES

PROBLEM IDENTIFICATION

The critical path for the second phase runs through the interior finishes on floors three through six, as this is the only remaining work to be completed. Experience on the project proved that the critical path method (CPM) schedule presented unrealistic durations that were not met by the finish contractors. For this reason contractors were not able to flow continuously from floor to floor or space to space. Instead contractors were forced to mobilize each time workspace was available. This stems directly from the unrealistic durations and inability to create flow of trades and throughput of spaces. CPM scheduling has proven to be ineffective at correcting these issues, as it is not derived from production values.

Figure 7.1 compares the planned finish activity durations from the CPM schedule and the actual finish activity durations recorded in the updated CPM schedule. The planned durations are shown in light colors, while the actual durations are displayed in dark. As you can see, the actual durations during the interior finishes stage increased significantly over the planned durations.

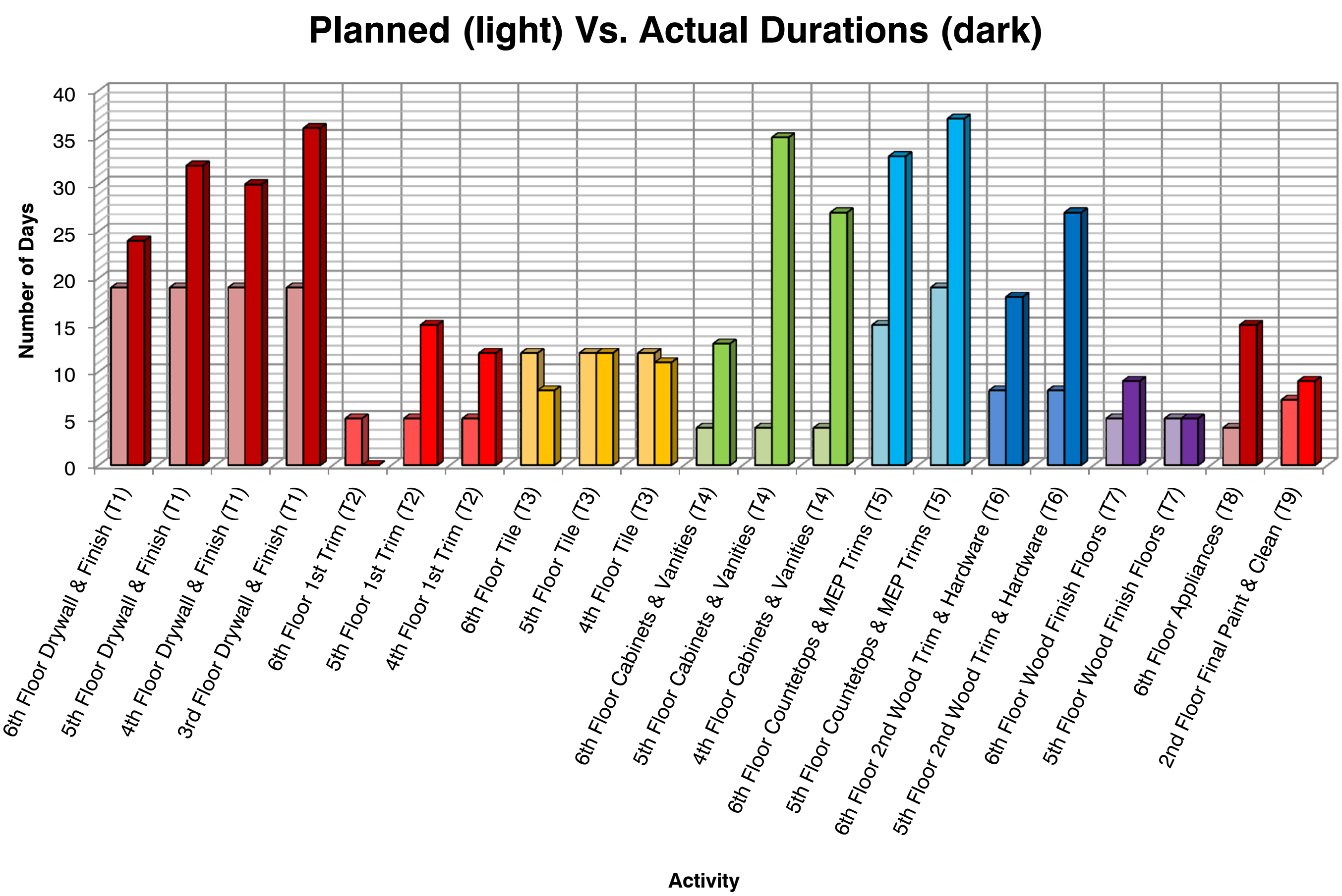


Figure 7.1. Planned Vs. Actual Durations

SOLUTION

This analysis will be used to determine a scheduling method to produce a more detailed and predictable plan that is more fluid and enables smooth work flow through the spaces.

Short interval production scheduling (SIPs) is a scheduling technique that is used do derive a predictable schedule using accurate production rates. This approach to scheduling has been implemented on construction projects that incorporate repetitive processes. Taking an assembly line approach to construction, the building is divided into similar spaces and workers move through the building in a sequential pattern. With constant durations, each crew is given the same amount of time to complete their work in a space before moving to the next.

This approach seen at the right in Figure 7.2, was used on the Pentagon renovation project which started in March of 2002 and had an initial 42 week schedule. The schedule involved forty 10,000 SF areas and 26 major activities. The renovation project used week durations for the spacing resulting in 26 weeks of renovation per space. This numbers may seem high, however, the “waterfall” effect of short interval production scheduling results in turnover of a space per week and an overall renovation duration of 65 weeks. Although the schedule duration was increased, it is important to note that SIPS provided a predictable schedule that was ultimately met.

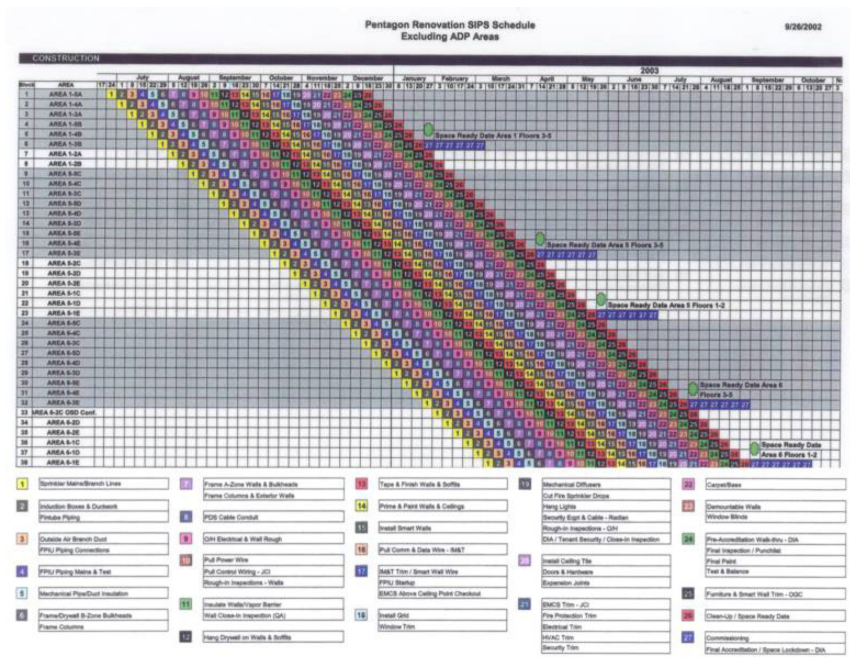


Figure 7.2. SIPS Pentagon Renovation
Source: http://renovation.pentagon.mil/wedge2-5/sips.htm

Similar to the Pentagon renovation project, Solaire Wheaton has a large building footprint with fairly repetitive spaces. This analysis will present an implementation of short interval production scheduling on the second phase of the project for the interior trades in the residential units on floors three through six. Short interval production scheduling provides an easier way to manage specialty contractors, plan, and schedule work. This scheduling method eliminates stacking of the trades, while allowing for cleaner and less congested work areas. This also allows for specialty contractors to level their resources. Instead of having to mobilize multiple times because work areas are not ready, crew sizes can remain constant.

ANALYSIS

The first step to perform a SIPS analysis is to determine the sequence of activities. This was done by examining the actual CPM schedule and by drawing on personal experience on the project. This is reflected in the sequence and grouping of activities on the following page. The next step was to use pull planning to determine the optimal number of sections per floor and days per section to meet the planned completion date. With a planned interior finishes duration of 27 weeks and 11 trades, a 5 day duration per section produced a overall interior finishes duration of 26 weeks.

The simplest way to divide the floor was into four sections as can be seen in Figure 7.3. With a total of 44 units per floor on levels three through six, this produced an average of eleven units per section. With eleven tasks and sixteen sections to complete, this yields a 26 week period using five days per section.

Figure 7.3 also demonstrates the flow of work horizontally and vertically throughout the building. Being that the design of floors 3 through 6 takes a "U-shape" to accommodate the open courtyard, flow cannot continue around a floor completely. Interior work will start on the 6th floor in a top down flow. Work starts on the east side adjacent to Georgia Avenue and continues counter-clockwise to the southwest corner. At this point work will descend to the 5th floor and continue in a clockwise pattern. This prevents workers from having to move material and equipment all the way back around the floor and down. This pattern which creates the shortest path is repeated on the lower floors.

The top-down sequence allow waste to come down and out of the building without tracking through completed space as well as minimize damage to completed spaces due to settlement of the wood structure.

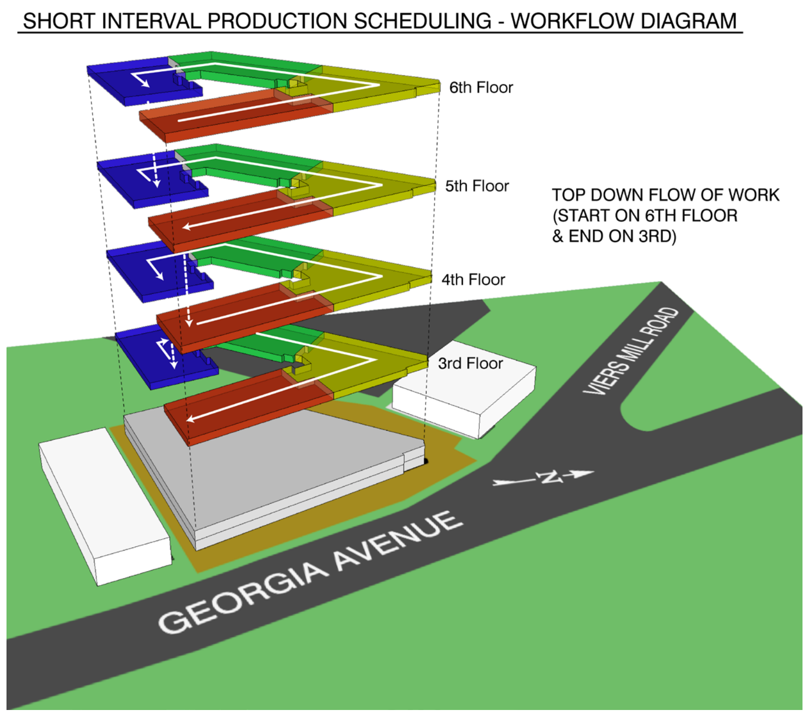


Figure 7.3. SIPS Sections & Work flow

Next, production rates need to be estimated or calculated. Because these production rates are difficult to estimate, they were calculated using actual data from the project. By examining superintendent daily reports for manpower and the updated schedule for actual durations, production rates were calculated. As seen in Table 7.1 on the next page, production was defined as work hours per floor. This was then divided by four to determine the production rate required to complete each of the four sections per floor on time. Once the section production rate was calculated, the required manpower could be backed out by calculation. Using the known production rate, estimated eight hour work days, and the planned five days per section, the manpower is calculated.

SIPS Duration Calcuation							
Activity		Actual Duration (Days/Floor)	Average Manpower (workers)	Actual Production (wk hrs/floor)	SIPS Production (wk hrs/section)	SIPS Duration (Days /Section)	SIPS Manpower Required (workers)
		Data from Project Superintendent Daily Reports & CPM Schedule			Actual Duration * Avg.Manpower * 8 hrs/day	Average Actual Production/ 4 sections	SIPS Production / (SIPS Duration * 8)
T1 - Drywall & Finish	6th Floor	24	12	2304	732	5	18
	5th Floor	32	12	3072			
	4th Floor	30	12	2880			
	3rd Floor	36	12	3456			
	Average			**2928**			
T2 - 1st Trim	6th Floor	N/A	N/A	N/A	108	5	3
	5th Floor	15	4	480			
	4th Floor	12	4	384			
	Average			**432**			
T3 - Tile	6th Floor	8	2	128	41	5	1
	5th Floor	12	2	192			
	4th Floor	11	2	176			
	Average			**165**			
T4 - Cabinets & Vanities	6th Floor	13	4	416	200	5	5
	5th Floor	35	4	1120			
	4th Floor	27	4	864			
	Average			**800**			
T5 - Countetops & MEP Trims	6th Floor	33	12	3168	840	5	21
	5th Floor	37	12	3552			
	Average			**3360**			
T6 - 2nd Wood Trim & Hardware	6th Floor	18	6	864	270	5	7
	5th Floor	27	6	1296			
	Average			**1080**			
T7 - Wood Finish Floors	6th Floor	9	2	144	28	5	1
	5th Floor	5	2	80			
	Average			**112**			
T8 - Appliances	6th Floor	15	3	360	90	5	2
	Average			**360**			
T9 - Final Paint & Clean	2nd Floor	9	8	576	144	5	4
	Average			**576**			
T10 - CBG Punchlist & Correction	Average	-	-	-	-	5	-
T11 - Owner Punchlist & Correction	Average	-	-	-	-	5	-

Table 7.1. Production Rate Calculation

The final step is to produce a matrix schedule for the project team to follow. As can be seen in Figure 7.4, this matrix schedule provides a management tool to check progress. Each specialty contractor is able to schedule a constant number of men on the project for 16 weeks. This is a tremendous positive effect of applying short interval scheduling at a large scale. The continuous mobilization and demobilization associated with mismanagement of the schedule is when many specialty contractors lose money and become discontent leading to a less successful project.

SIPS Schedule (3rd-6th Floor Units)

Section		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23	W24	W25	W26
Floor 6	Area 1	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11															
	Area 2		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11														
	Area 3			T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11													
	Area 4				T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11												
Floor 5	Area 1					T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11											
	Area 2						T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11										
	Area 3							T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11									
	Area 4								T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11								
Floor 4	Area 1									T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11							
	Area 2										T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11						
	Area 3											T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11					
	Area 4												T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11				
Floor 3	Area 1													T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11			
	Area 2														T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11		
	Area 3															T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	
	Area 4																T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11

		# of Contractors	Contractors
T1	Drywall & Finish	1	Charly Drywall
T2	1st Trim	1	Kelly Trim
T3	Tile	1	CB Flooring
T4	Cabinets & Vanities	1	Crown America International (CAI)
T5	Countertops & MEP Trims	5	Ellis, Power Design, Breeden Mechanical, Mid-Atlantic Air, Castle Sprinkle
T6	2nd Wood Trim & Hardware	2	Kelly Trim, Contract Hardawre
T7	Wood Finish Floors	1	CB Flooring
T8	Appliances	1	Apollo
T9	Final Paint & Clean	2	Charly Drywall & Fresco Cleaning
T10	CBG Punchlist & Correction		
T11	Owner Punchlist & Correctior		

Figure 7.4. SIPS Matrix Schedule

DETAILED BREAKDOWN OF DRYWALL TRADE

Due to the high results of manpower for specific trades such as drywall & finish, a more detailed short interval schedule breakdown is sometimes necessary. This will help visualize the flow of workers through the space, creating an easily executable and manageable plan. To perform this part of the analysis, the East section of the 6th floor seen in Figure 7.5 was chosen.

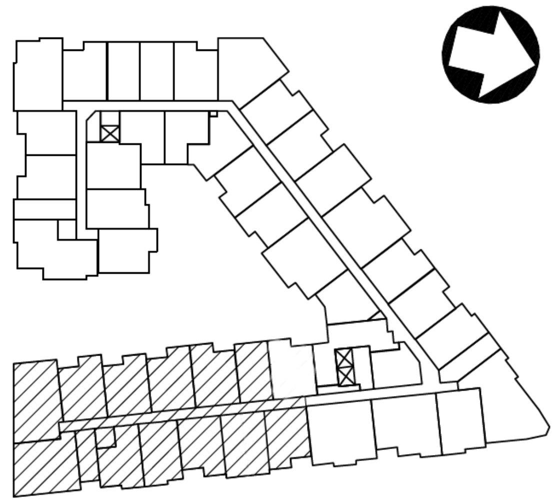


Figure 7.5. Estimated Production Rates

The first step was to determine the sequence of activities and estimate production rates. The sequence of activities is as follows:

- Exterior drywall
- Ceiling resilient channel
- Ceiling drywall
- Interior drywall
- Mud and sand
- Prime and first coat

This sequence reflects what was actually done on the project and was a product of the wall assembly type. The production rates were estimated using Rs Means 2014 as well as personal experience on the project. These numbers are shown in Table 7.2 and are the basis of the activity breakdown for this section of the floor.

Estimated Production Rates				
Activity	Crew	Unit	Daily Output	Labor Hours
Drywall (5/8" thick on walls - no finish)	2 carp	SF	2000	0.008
Drywall (5/8" thick on walls - taped and finished)	2 carp	SF	965	0.017
Drywall (5/8" thick on walls - skim coat finish)	2 carp	SF	775	0.021
Drywall (5/8" thick on ceilings - no finish)	2 carp	SF	1600	0.01
Drywall (5/8" thick on ceilings - taped and finished)	2 carp	SF	680	0.024
Drywall (5/8" thick on ceilings - skim coat finish)	2 carp	SF	545	0.029
Finish & Sand	2 carp	SF	5000	-
Resilient Channel (ceiling - 12" O.C.)	1 carp	CLF	25	-
Paint (walls - sprayer primer plus one finish coat)	1 Pord	SF	9000	-

Table 7.2. Estimated Production Rates

The next step was to perform a takeoff to determine the quantities which would be used to calculate durations using the estimated production rates. In Table 7.3 you can see this takeoff quantities. As you can see, the section was split into two major groups by unit size. Units 601 & 602 are corner units and are slightly larger. The remaining units are fairly similar in size and quantities of material.

T1 - Dyrwall and Finish							
Layout Type		SF Ceiling	LF Ext. Wall	SF Ext. Wall	LF Int. Wall	SF Int. Wall	RC Channel
			Avg. h=10.5'	LF*h*2 layers	Avg. h=9'	LF*h	Avg. CLF
Unit 601	B2.00	1,062	68	714	195	1,755	7.2
Unit 602	B8.00	1,032	40	420	185	1,665	
Totals		**2,094**		**1,134**		**3,420**	
Average		**1,047**		**567**		**1,710**	**7.2**
Unit 603	A3.00	630	25	263	148	1,332	6.3
Unit 604	A8.00	758	25	263	154	1,386	
Unit 605	A8.01	788	25	263	168	1,512	
Unit 606	A8.04	758	25	263	154	1,386	
Unit 607	A13a.00	746	25	263	156	1,404	
Unit 608	AD1.01	710	25	263	156	1,404	
Unit 609	A12.00	670	22	231	125	1,125	
Unit 610	A10.02	758	25	263	150	1,350	
Unit 611	A13.01	747	24	252	156	1,404	
Unit 612	A2.01	623	18	189	150	1,350	
Totals		**7,188**		**2,510**		**13,653**	
Remaining Average		**719**		**456**		**2,482**	**6.3**

Table 7.3. Quantity Takeoffs

Using the quantity takeoffs and production rates as well as a fixed duration goal, manpower can be calculated and distributed to meet the maximum of 19 workers. In this case, the duration goal was 3 hours for units 601 & 602, while the duration for the remaining units is 2 hours as seen in Table 7.4.

Calculated Durations (Units 601 & 602)								
Task	Unit	Takeoff	Men/Crew	Daily Crew Production	# of Crews	Total Manpower	Hourly Production	Duration (hour)
						men/crew * # of crews	daily production/8 hr	Takeoff/ (# of crews * hourly production
Exterior Wall Drywall	SF	567	2	2000	1	2	250	2.3
Ceiling Resilient Channel	CLF	7.2	2	25	1	2	3.125	2.3
Ceiling Drywall	SF	1,047	2	1600	2	4	200	2.6
Interior Wall Drywall	SF	1,710	2	2500	2	4	312.5	2.7
Finish & Sand	SF	3,324	2	5000	2	4	625	2.7
Prime & One Coat	SF	3,324	2	9000	1	2	1125	3.0
Total						**18**		

Calculated Durations (Remaining Units)								
Task	Unit	Takeoff	Men/Crew	Daily Crew Production	# of Crews	Total Manpower	Hourly Production	Duration (hour)
						men/crew * # of crews	daily production/8 hr	Takeoff/ (# of crews * hourly production
Exterior Wall Drywall	SF	251	1	1000	1	1	125	2.0
Ceiling Resilient Channel	CLF	6.3	2	25	1	2	3.125	2.0
Ceiling Drywall	SF	719	2	1600	2	4	200	1.8
Interior Wall Drywall	SF	1,356	2	2500	2	4	312.5	2.2
Finish & Sand	SF	3,657	2	5000	2.5	5	625	2.3
Prime & One Coat	SF	3,657	2	9000	1.5	3	1125	2.2
Total						**19**		

Table 7.4. Calculated Durations

Below, in Figure 7.6, you see the matrix schedule for the drywall and finish trade. As shown, the larger units (601 & 602) have three hour duration while the remaining units have a 2 hour activity duration. The gray sections denote time allocated for cleanup and material staging. This is used to keep the workspace clean and productive while ensuring that cleanup of the space is not left until the end. This type of scheduling requires workers to be multi-skilled so that crews can adapt to keep on schedule.

T1 - Dyrwall and Finish

Tasks	Day 1								Day 2							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Exterior Drywall (2 layers 5/8" type X)	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	
Ceiling Resilient Channel				2	2	2	2	2	2	2	2	2	2	2	2	
Ceiling Drywall (1 layer 5/8" type X)							4	4	4	4	4	4	4	4	4	
Interior Drywall (1 layer 5/8" type X)										4	4	4	4	4	4	
Finish & Sand													4	4	4	
Prime & One Finish Coat																
Total Manpower	2	2	2	4	4	4	7	7	7	11	11	11	15	15	15	19

Tasks	Day 3								Day 4								Day 5							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Exterior Drywall (2 layers 5/8" type X)	1	1	1	1	1	1	1																	
Ceiling Resilient Channel	2	2	2	2	2	2	2		2	2	2													
Ceiling Drywall (1 layer 5/8" type X)	4	4	4	4	4	4	4		4	4	4	4	4	4										
Interior Drywall (1 layer 5/8" type X)	4	4	4	4	4	4	4		4	4	4	4	4	4	4		4	4						
Finish & Sand	4	4	4	5	5	5	5		5	5	5	5	5	5	5		5	5	5	5	5			
Prime & One Finish Coat	2	2	2	2	2	2	3		3	3	3	3	3	3	3		3	3	3	3	3	3	3	3
Total Manpower	17	17	17	18	18	18	19	19	18	18	18	16	16	16	12	19	12	12	8	8	8	3	3	3

Figure 7.6. SIPS Schedule

As illustrated in Figure 7.7 below, the manpower of each trade will follow similarly to the overall manpower curve. Although you see many ups and downs in the curve, this does not account for all of the ancillary tasks which need to be completed such as movement of material and cleanup of the space. These tasks will take place during the down time and the manpower will remain constant at 19 as shown in blue.

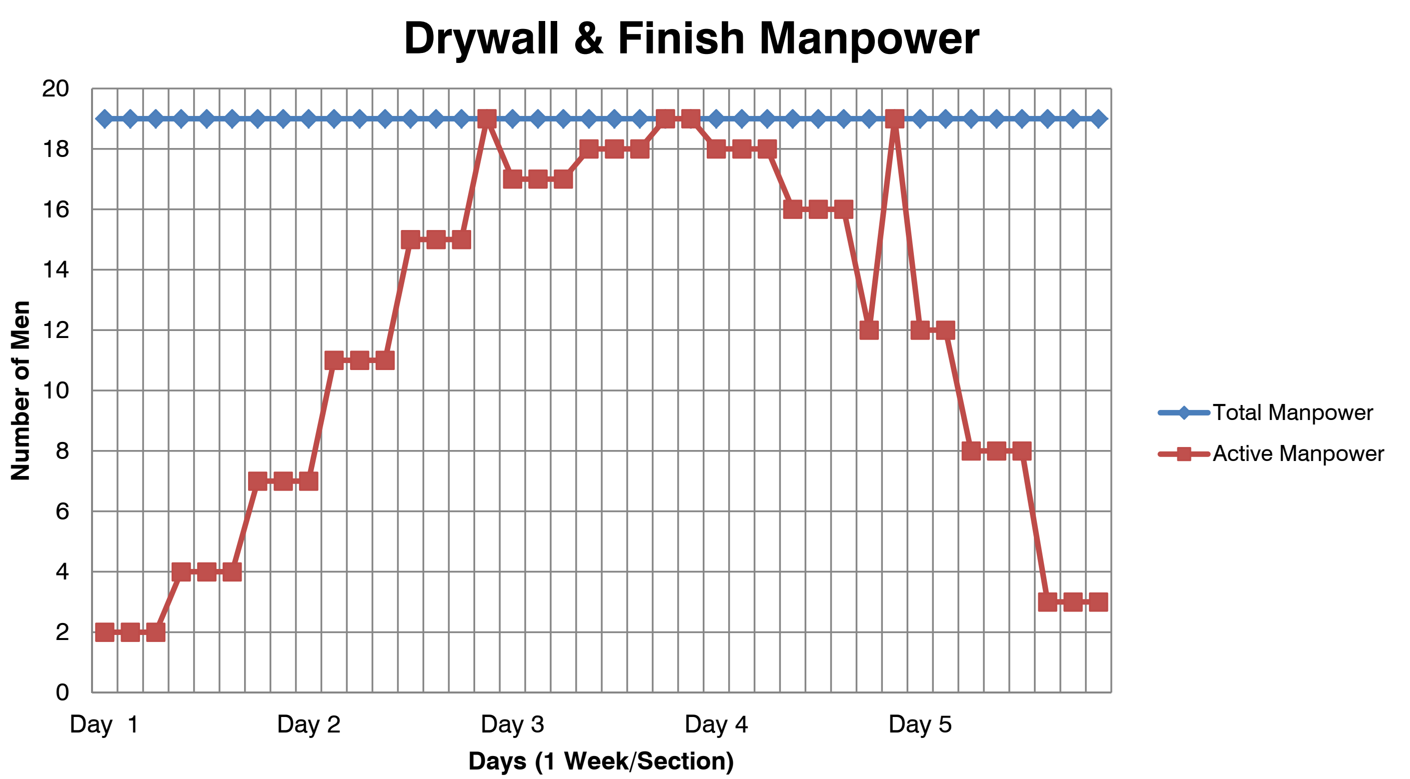
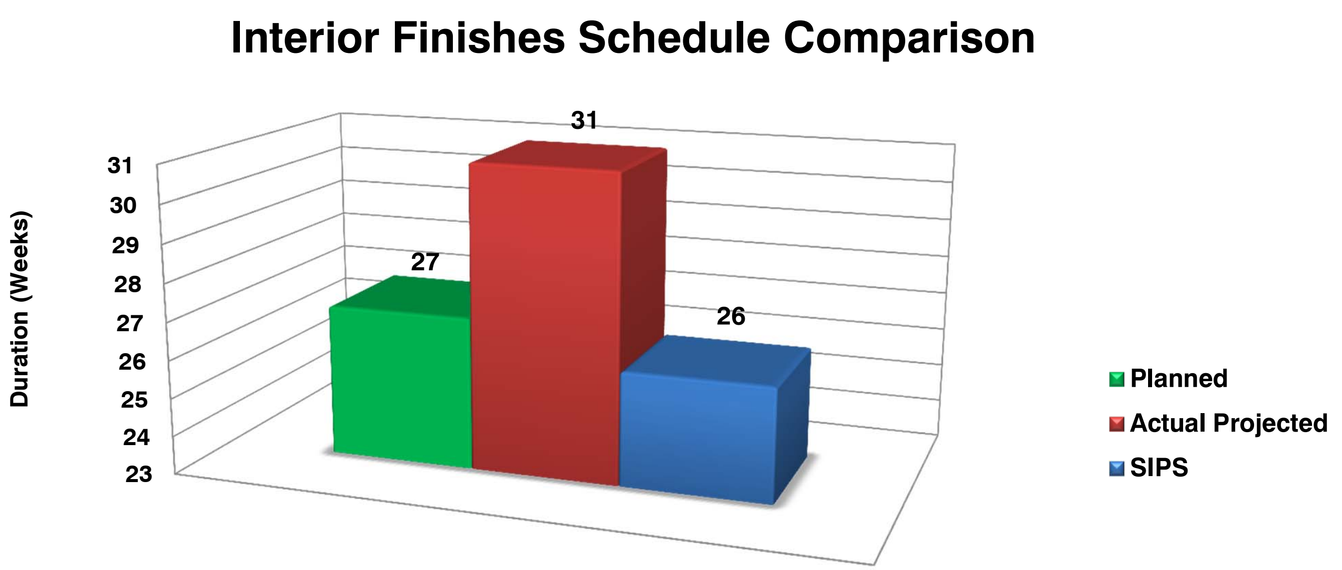


Figure 7.7. Manpower Curve

OUTCOME

As illustrated so far, implementation of short interval production scheduling provides a more accurate and detailed plan. This will make the interior finishes stage more predictable for all parties involved. The contractor and owner will not have to deal with delays and damage claims due to unmet schedule deadlines. Subcontractors will have a more predictable interior finishes plan from which they can form their work plan. SIPs scheduling also provides an easier way for the construction manager or general contractor to manage the trades and track progress.

As seen in Figure 7.8, the short interval production schedule should result in a schedule duration that is one week shorter than the planned duration. With this scheduling technique, there should be no schedule increases as there were with the CPM scheduling method used on the project.



	Total Weeks
Planned	27
Actual Projected	31
SIPS	26

Figure 7.8. Scheduling Comparison

The effect of short interval production scheduling on manpower levels is illustrated below, in Figure 7.9. The SIPS manpower curve shown in blue grows at a fairly constant rate to the point where it plateaus for several weeks before descending at a predictable and fairly constant rate. The actual manpower levels are shown in red and are highly unpredictable. Because the project has yet to be completed at the time of research, the projected manpower levels are illustrated with a dotted red line.

Although this may seem like a menial effect of this scheduling method, having consistent and predictable manpower levels aids in the project management division. The burden on specialty contractors is reduced as there are consistent crew sizes and a single mobilization.

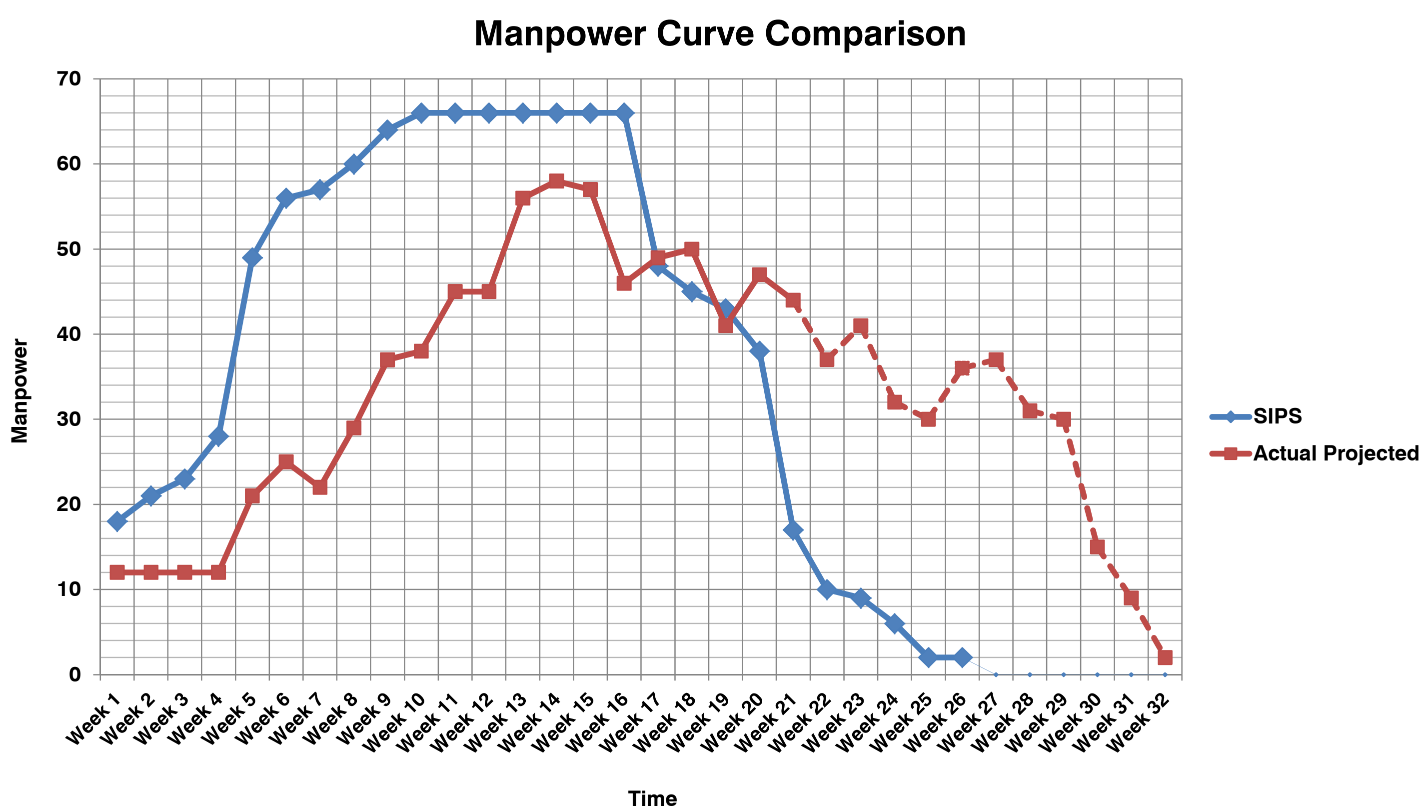


Figure 7.9. Manpower Comparison

In addition to the schedule savings associated with implementing the short interval production scheduling, the project team should also see some general conditions cost savings. With an average weekly general conditions cost of $23,706, the schedule reduction using SIPS provides an estimated $118,527 in savings. Although this amount is overshadowed by the guaranteed maximum price of $31.5 million, the savings could be poured back into the buildings design. The extra money could be used to seek energy savings by upgrading the windows or using higher end finishes, which would presumably increase the rate of return on investment for the owner of the building.

SIPS CONCERNS

Some of the concerns related to short interval production scheduling implementation are:

- Buy-in from the trade contractors - in order for the estimated schedule to be fulfilled, each of the trade contractors need to be committed from the beginning and willing to work in this atypical fashion.

- Manpower capabilities - as you have seen through this analysis, in order to complete the interior finishes phase in 26 weeks, manpower for some of the trades was increased significantly.

- The domino effect of a missed deadline - if one trade misses a deadline, this will cause the follow-on trades to be delayed as well.

These concerns are manageable; however, they need to be recognized and dealt with by the project team.

MAE REQUIREMENTS

This analysis was based on lessons learned in the AE 570 course, better known as Production Management in Construction. Short interval production scheduling was a concept learned through AE 570. The Pentagon Renovation project was presented in this class and is the model for the implementation of SIPS on the Solaire Wheaton project.

CONCLUSION

As this analysis demonstrates, short interval production scheduling is an incredible tool for predicting schedule durations. In contrast with critical path method scheduling, SIPS uses calculated production rates increasing the accuracy of the schedule.

A record keeping of production rates is an extremely valuable tool. A good way of organizing them would be by project type, such as hospital or apartment building. For example, this data can be used on similar podium structure residential apartment buildings.

Schedule overruns are a major problem in the construction industry. They are almost guaranteed with the critical path method schedule. The construction industry could learn from the manufacturing industry and use this short interval production scheduling technique to deliver projects on time inherently increasing the quality of service and level of client satisfaction.

SCHEDULE ACCELERATION SUMMARY AND CONCLUSIONS

The implementation of modularization and short interval production scheduling will result in an overall schedule reduction of nine weeks. Although modularization had a four month on-site reduction and SIPs had a five week on-site reduction, the critical path causes the overall schedule reduction to be limited to nine weeks as seen in Figure 8.1 on the following page.

It can be concluded that if modularization had been included interior finishes and even building enclosure, the schedule could have been reduced even more. The disadvantage of that, is that module construction would need to start earlier and the design fast-tracked even more.

As short interval production scheduling is adjustable, the interior finishes schedule could be reduced more; however, required manpower will be increased. This increase in manpower will cause more congestion and productivity loss. For that reason, there is an optimum point where productivity and schedule acceleration can both be maximized using short interval production scheduling.

Both of these construction and scheduling methods are fairly new in the industry and have yet to be broadly adopted. These analyses demonstrate the cost and schedule saving effects of their implementation on projects such as Solaire Wheaton.

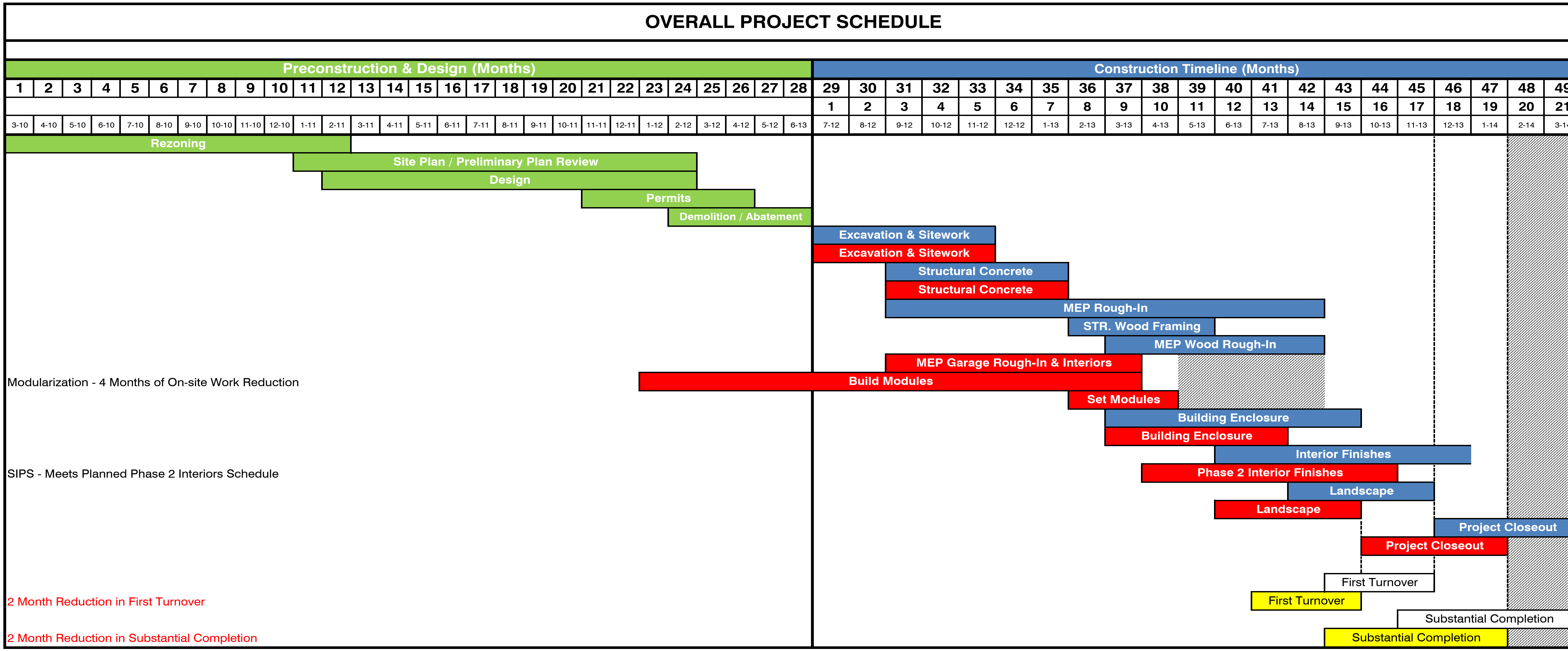


Figure 8.1. Overall Schedule Savings

The combination of schedule savings associated with implementing modularization and short interval production scheduling will result in minor cost savings.

As you can see in Table 8.1, the two month schedule reduction using modularization provides an estimated $175,562 in cost savings. Using SIPs, the actual schedule is reduced by five weeks, resulting in $118,527 in general conditions savings.

As you can see, the total amount of cost savings comes to over a quarter of a million dollars. Although this translates to only a 0.93% reduction in the guaranteed maximum price of $31.5 million, the savings could be poured back into the buildings design. The extra money could be used to seek energy savings by upgrading the windows or using higher end finishes, which would presumably increase the rate of return on investment for the owner of the building.

Overall Cost Savings	
Analysis	**Cost Reduction**
Modularization	$175,562.32
SIPs General Conditions	$118,527.00
Total Savings	**$294,089.32**
% of GMP ($31.5 m)	**0.93%**

Table 8.1. Overall Cost Savings

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Analysis 4 - SIPs for Interior Finishes

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APPENDIX A. NOAA WEATHER DATA

02/16/2014

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Summary of Monthly Normals 1981-2010

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: **COLLEGE PARK, MD US** GHCND:USC00181995

Elev: 89 ft. Lat: 38.983° N Lon: 76.950° W

Temperature (°F)

Mean							Cooling Degree Days Base (above)						Heating Degree Days Base (below)				Mean Number of Days					
Month	Daily Max	Daily Min	Mean	Long Term Max Std. Dev.	Long Term Min Std. Dev.	Long Term Avg Std. Dev.	55	57	60	65	70	72	55	57	60	65	Max >= 100	Max >= 90	Max >= 50	Max <= 32	Min <= 32	Min <= 0
1	43.4	26.2	34.8	5.0	4.6	4.7	2	1	1	-7777	0	0	628	689	782	936	0.0	0.0	7.1	4.2	22.4	0.6
2	47.4	28.5	37.9	4.0	3.6	3.6	4	2	1	-7777	0	0	481	535	618	757	0.0	0.0	10.3	1.6	18.6	0.0
3	55.5	35.0	45.2	3.5	2.1	2.7	30	21	12	5	1	1	332	385	469	617	0.0	0.1	19.6	0.4	12.4	0.0
4	67.0	44.5	55.8	2.9	1.9	2.2	118	90	57	22	6	3	96	128	185	300	0.0	0.5	28.8	0.0	2.0	0.0
5	76.4	54.2	65.3	3.5	2.8	3.0	329	275	202	108	46	29	10	18	38	98	0.1	2.4	31.0	0.0	0.0	0.0
6	84.8	64.1	74.4	2.6	1.8	1.9	584	524	436	294	169	127	1	1	3	10	0.1	7.9	30.0	0.0	0.0	0.0
7	88.7	69.4	79.0	2.6	2.0	2.1	745	683	590	436	284	226	0	0	-7777	-7777	0.3	13.2	31.0	0.0	0.0	0.0
8	87.4	66.9	77.2	2.4	2.2	2.1	687	625	532	379	231	179	0	-7777	-7777	2	0.3	11.2	31.0	0.0	0.0	0.0
9	80.4	59.6	70.0	2.4	1.6	1.7	452	394	310	187	95	67	2	4	10	37	0.2	3.2	30.0	0.0	0.0	0.0
10	69.1	47.0	58.1	3.1	3.0	2.7	158	122	77	30	10	6	63	90	138	245	0.0	0.1	31.0	0.0	1.1	0.0
11	58.7	38.0	48.3	3.6	2.5	2.8	34	22	11	2	-7777	-7777	233	281	361	502	0.0	0.0	23.9	0.0	8.0	0.0
12	46.9	30.2	38.5	5.5	4.0	4.6	6	4	2	-7777	0	0	516	575	666	820	0.0	0.0	12.0	2.8	18.5	0.0
Summary	67.1	47.0	57.0	3.4	2.7	2.8	3149	2763	2231	1463	842	638	2362	2706	3270	4324	1.0	38.6	285.7	9.0	83.0	0.6

@ Denotes mean number of days greater than 0 but less than 0.05; or insufficient data for calculation.

-4444: year-round risk of frost-freeze

-6666: parameter undefined; insufficient occurrences to compute value

-7777: a non-zero value that would round to zero

9999, Empty, or blank, cells indicate an average greater than 0 but less than 0.05.

Precipitation (in.)

	Totals	Mean Number of Days				Precipitation Probabilities Probability that precipitation will be equal to or less than the indicated amount		
	Means	Daily Precipitation				Monthly Precipitation vs. Probability Levels		
Month	Mean	>= 0.01	>= 0.10	>= 0.50	>= 1.00	.25	.50	.75
1	2.96	9.4	6.0	2.2	0.4	2.41	2.75	3.19
2	2.91	9.0	6.0	1.9	0.4	1.99	2.74	3.67
3	3.49	8.9	6.4	2.7	1.1	2.15	3.44	4.37
4	3.29	8.8	6.2	2.6	0.7	2.29	3.23	4.27
5	4.40	10.5	7.8	3.7	1.5	2.74	4.23	5.73
6	3.81	8.2	5.5	2.5	0.9	2.30	3.93	4.92
7	4.85	9.5	5.8	2.8	1.3	3.65	4.48	5.74
8	3.56	9.0	6.4	2.4	1.0	2.07	3.62	4.72
9	4.00	7.9	6.1	2.4	0.9	1.96	3.12	5.87
10	3.50	7.7	4.8	2.6	0.7	1.80	3.03	5.20
11	3.51	8.0	5.4	2.9	0.9	1.98	4.02	4.89
12	3.45	9.4	5.9	2.1	0.7	1.94	3.09	4.79

02/16/2014

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Monthly Climatological Summary (2012)

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Date	Temperature (°F)											Precipitation (in.)						
Elem->	MMXT	MMNT	MNTM	HTDD	CLDD	EMXT	EMNT	DT90	DX32	DT32	DT00	TPCP	EMXP	TSNW	MXSD	DP01	DP05	DP10
Month	Mean Max.	Mean Min.	Mean	Heating Degree Days	Cooling Degree Days	Highest	Lowest	Number Of Days Max>=90°	Max<=32°	Min<=32°	Min<=0°	Total	Greatest Observed	Snow, Sleet, Hail Total Fall	Max Depth	Number Of Days >=.10	>=.50	>=1.0
1												2.18	1.27	1.6	1	2	2	1
2												0.56	0.20	0.0	0	3	0	0
3												3.54	1.42	0.0	0	4	3	2
4												2.12	1.38	0.0		4	1	1
5												2.15	0.95	0.0		6	1	0
6												1.76	0.58	0.0		5	2	0
7												0.63	0.27	0.0		3	0	0
8												3.26	0.65	0.0		9	1	0
9												1.39	0.88	0.0		4	1	0
10												7.68	4.94	0.0		7	4	1
11												0.87	0.65	0.0		1	1	0
12												0.32	0.14	0.0		1	0	0
Summary												26.46	4.94	1.6	1	49	16	5

02/16/2014

U.S. Department of Commerce
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Monthly Climatological Summary (2013)

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Federal Building
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Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Date	**Temperature (°F)**											**Precipitation (in.)**						
Elem->	MMXT	MMNT	MNTM	HTDD	CLDD	EMXT	EMNT	DT90	DX32	DT32	DT00	TPCP	EMXP	TSNW	MXSD	DP01	DP05	DP10
Month	Mean Max.	Mean Min.	Mean	Heating Degree Days	Cooling Degree Days	Highest	Lowest	Number Of Days: Max>=90°	Max<=32°	Min<=32°	Min<=0°	Total	Greatest Observed	Snow, Sleet, Hail: Total Fall	Max Depth	Number Of Days: >=.10	>=.50	>=1.0
1												1.90	1.65	2.0	2	1	1	1
2												1.01	0.39	0.8	1	4	0	0
3												1.00	0.41	2.5	3	3	0	0
4												0.38	0.29	0.0		1	0	0
5												2.35	0.87	0.0		3	3	0
6												6.13	1.75	0.0		9	5	2
7												1.97	1.12	0.0		5	1	1
8												1.48	0.46	0.0		5	0	0
9												0.10	0.10	0.0		1	0	0
10												6.15	2.59	0.0		5	3	3
11												2.35	2.28	0.0		1	1	1
12												2.59	1.14	3.3	2	3	2	2
Summary												27.41	2.59	8.6	3	41	16	10

04/05/2014

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Record of Climatological Observations

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Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2012	7	1				0.00		0.0										
	2012	7	2				0.00		0.0										
	2012	7	3				0.00		0.0										
	2012	7	4				0.10												
	2012	7	5				0.00		0.0										
	2012	7	6				0.00		0.0										
	2012	7	7				0.00		0.0										
	2012	7	8				0.00		0.0										
	2012	7	9				0.20												
	2012	7	10				0.05												
	2012	7	11				0.27												
	2012	7	12																
	2012	7	13																
	2012	7	14																
	2012	7	15																
	2012	7	16																
	2012	7	17																
	2012	7	18																
	2012	7	19																
	2012	7	20																
	2012	7	21																
	2012	7	22																
	2012	7	23																
	2012	7	24																
	2012	7	25				0.00		0.0										
	2012	7	26				0.00		0.0										
	2012	7	27				0.01												
	2012	7	28				0.00		0.0										
	2012	7	29				0.00		0.0										
	2012	7	30				0.00		0.0										
	2012	7	31				0.00		0.0										
Summary							0.63		0.0										

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Empty, or blank, cells indicate that a data observation was not reported.
*Ground Cover: 1=Grass; 2=Fallow; 3=Bare Ground; 4=Brome grass; 5=Sod; 6=Straw mulch; 7=Grass muck; 8=Bare muck; 0=Unknown
"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
"A" values in the Precipitation Flag or the Snow Flag column indicate a multiday total, accumulated since last measurement, is being used.
Data value inconsistency may be present due to rounding calculations during the conversion process from SI metric units to standard imperial units.

04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Min.	at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	Max.	Min.	8 in depth Ground Cover (see *)	Max.	Min.
	2012	8	1				0.14												
	2012	8	2				0.00		0.0										
	2012	8	3				0.00		0.0										
	2012	8	4				0.00		0.0										
	2012	8	5				0.00		0.0										
	2012	8	6				0.47												
	2012	8	7				0.00		0.0										
	2012	8	8				0.00		0.0										
	2012	8	9				0.00		0.0										
	2012	8	10				0.65												
	2012	8	11				0.19												
	2012	8	12				T												
	2012	8	13				0.00		0.0										
	2012	8	14				0.10												
	2012	8	15				0.03												
	2012	8	16				0.00		0.0										
	2012	8	17				0.00		0.0										
	2012	8	18				0.28												
	2012	8	19				0.00		0.0										
	2012	8	20				0.38												
	2012	8	21				0.49												
	2012	8	22				0.00		0.0										
	2012	8	23				0.02												
	2012	8	24				0.00		0.0										
	2012	8	25				0.00		0.0										
	2012	8	26				0.02												
	2012	8	27				0.43												
	2012	8	28				0.05												
	2012	8	29				0.01												
	2012	8	30				0.00		0.0										
	2012	8	31				0.00		0.0										
Summary							3.26		0.0										

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*Ground Cover: 1=Grass; 2=Fallow; 3=Bare Ground; 4=Brome grass; 5=Sod; 6=Straw mulch; 7=Grass muck; 8=Bare muck; 0=Unknown
"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
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Data value inconsistency may be present due to rounding calculations during the conversion process from SI metric units to standard imperial units.

04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time			Precipitation(see **) 24 Hour Amounts ending at observation time				At Obs Time	Evaporation		Soil Temperature (°F) 4 in depth			8 in depth		
				Max.	Min.	at Observation	Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2012	9	1				0.00		0.0										
	2012	9	2				0.01												
	2012	9	3				0.11												
	2012	9	4				0.08												
	2012	9	5				0.00		0.0										
	2012	9	6				0.00		0.0										
	2012	9	7				0.11												
	2012	9	8				0.00		0.0										
	2012	9	9				0.88												
	2012	9	10				0.00		0.0										
	2012	9	11				0.00		0.0										
	2012	9	12				0.00		0.0										
	2012	9	13				0.00		0.0										
	2012	9	14				0.00		0.0										
	2012	9	15				0.00		0.0										
	2012	9	16				0.00		0.0										
	2012	9	17				0.00		0.0										
	2012	9	18				0.20												
	2012	9	19																
	2012	9	20																
	2012	9	21																
	2012	9	22																
	2012	9	23																
	2012	9	24																
	2012	9	25																
	2012	9	26																
	2012	9	27																
	2012	9	28																
	2012	9	29																
	2012	9	30																
Summary							1.39		0.0										

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03/04/2014

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Federal Building
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Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation(see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2012	10	1																
	2012	10	2																
	2012	10	3																
	2012	10	4																
	2012	10	5																
	2012	10	6				0.00		0.0										
	2012	10	7				0.00		0.0										
	2012	10	8				0.14												
	2012	10	9				0.07												
	2012	10	10				T												
	2012	10	11				0.00		0.0										
	2012	10	12				0.00		0.0										
	2012	10	13				0.00		0.0										
	2012	10	14				0.00		0.0										
	2012	10	15				0.00		0.0										
	2012	10	16				0.21												
	2012	10	17				0.00		0.0										
	2012	10	18				0.00		0.0										
	2012	10	19				0.77												
	2012	10	20				0.64												
	2012	10	21				0.00		0.0										
	2012	10	22				0.00		0.0										
	2012	10	23				0.00		0.0										
	2012	10	24				0.00		0.0										
	2012	10	25				0.00		0.0										
	2012	10	26				0.00		0.0										
	2012	10	27				0.00		0.0										
	2012	10	28				0.00		0.0										
	2012	10	29				0.63												
	2012	10	30				4.94												
	2012	10	31				0.27												
Summary							7.67		0.0										

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04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2012	11	1																
	2012	11	2																
	2012	11	3																
	2012	11	4																
	2012	11	5																
	2012	11	6																
	2012	11	7																
	2012	11	8																
	2012	11	9																
	2012	11	10																
	2012	11	11				0.00		0.0										
	2012	11	12				0.00		0.0										
	2012	11	13				0.65												
	2012	11	14				0.08												
	2012	11	15				0.00		0.0										
	2012	11	16				0.00		0.0										
	2012	11	17				0.00		0.0										
	2012	11	18				0.00		0.0										
	2012	11	19				0.00		0.0										
	2012	11	20				0.00		0.0										
	2012	11	21				0.00		0.0										
	2012	11	22				0.00		0.0										
	2012	11	23				0.00		0.0										
	2012	11	24				0.00		0.0										
	2012	11	25				0.00		0.0										
	2012	11	26				0.00		0.0										
	2012	11	27				0.06												
	2012	11	28				0.08												
	2012	11	29				0.00		0.0										
	2012	11	30				0.00		0.0										
Summary							0.87		0.0										

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2012	12	1				0.00		0.0										
	2012	12	2				0.00		0.0										
	2012	12	3				0.01												
	2012	12	4				0.00		0.0										
	2012	12	5				0.00		0.0										
	2012	12	6				0.00		0.0										
	2012	12	7				0.01												
	2012	12	8				0.01												
	2012	12	9				0.14												
	2012	12	10				0.05												
	2012	12	11				0.09												
	2012	12	12				0.00		0.0										
	2012	12	13																
	2012	12	14																
	2012	12	15																
	2012	12	16																
	2012	12	17																
	2012	12	18																
	2012	12	19																
	2012	12	20																
	2012	12	21																
	2012	12	22																
	2012	12	23																
	2012	12	24																
	2012	12	25																
	2012	12	26																
	2012	12	27																
	2012	12	28																
	2012	12	29																
	2012	12	30																
	2012	12	31																
Summary							0.31		0.0										

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Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2013	1	1																
	2013	1	2																
	2013	1	3																
	2013	1	4																
	2013	1	5																
	2013	1	6																
	2013	1	7																
	2013	1	8																
	2013	1	9																
	2013	1	10																
	2013	1	11																
	2013	1	12																
	2013	1	13																
	2013	1	14																
	2013	1	15																
	2013	1	16																
	2013	1	17																
	2013	1	18																
	2013	1	19																
	2013	1	20																
	2013	1	21				0.00		0.0										
	2013	1	22				0.00		0.0										
	2013	1	23				0.00		0.0										
	2013	1	24				0.04		1.0		1								
	2013	1	25				0.00		0.0		1								
	2013	1	26				0.05		1.0		2								
	2013	1	27				0.00		0.0		1								
	2013	1	28				0.03		0.0		1								
	2013	1	29				0.09		0.0		T								
	2013	1	30				T		0.0		0								
	2013	1	31				1.65												
Summary							1.86		2.0										

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*Ground Cover: 1=Grass; 2=Fallow; 3=Bare Ground; 4=Brome grass; 5=Sod; 6=Straw mulch; 7=Grass muck; 8=Bare muck; 0=Unknown
"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
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Data value inconsistency may be present due to rounding calculations during the conversion process from SI metric units to standard imperial units.

04/05/2014

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Federal Building
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www.ncdc.noaa.gov

Station: **SILVER SPRING 0.9 N, MD US** GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in Max.	4 in Min.	8 in depth Ground Cover (see *)	8 in Max.	8 in Min.
	2013	2	1																
	2013	2	2																
	2013	2	3				0.04		0.8		1								
	2013	2	4				T		T		T								
	2013	2	5				0.00		0.0		T								
	2013	2	6				0.00		0.0		0								
	2013	2	7				0.00		0.0		0								
	2013	2	8				0.12		0.0		0								
	2013	2	9				0.03		0.0		0								
	2013	2	10				0.00		0.0		0								
	2013	2	11				0.39		0.0		0								
	2013	2	12				0.01		0.0		0								
	2013	2	13				0.00		0.0		0								
	2013	2	14				0.28		T		T								
	2013	2	15				0.00		0.0		0								
	2013	2	16				0.14		0.0		0								
	2013	2	17				T		0.0		0								
	2013	2	18				0.00		0.0		0								
	2013	2	19																
	2013	2	20																
	2013	2	21																
	2013	2	22																
	2013	2	23																
	2013	2	24																
	2013	2	25																
	2013	2	26																
	2013	2	27																
	2013	2	28																
Summary							1.01		0.8										

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"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
"A" values in the Precipitation Flag or the Snow Flag column indicate a multiday total, accumulated since last measurement, is being used.
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04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown   Observation Time Precipitation: Unknown

Elev: 361 ft.   Lat: 39.027° N   Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2013	3	1																
	2013	3	2																
	2013	3	3																
	2013	3	4																
	2013	3	5																
	2013	3	6																
	2013	3	7																
	2013	3	8																
	2013	3	9																
	2013	3	10																
	2013	3	11																
	2013	3	12																
	2013	3	13																
	2013	3	14																
	2013	3	15				0.00		0.0										
	2013	3	16				0.00		0.0										
	2013	3	17				0.00		0.0										
	2013	3	18				0.00		0.0										
	2013	3	19				0.38												
	2013	3	20				0.00		0.0										
	2013	3	21				0.00		0.0										
	2013	3	22				0.00		0.0										
	2013	3	23				0.00		0.0										
	2013	3	24				0.00		0.0										
	2013	3	25				0.41		2.5		3								
	2013	3	26				0.21		T		1								
	2013	3	27																
	2013	3	28																
	2013	3	29																
	2013	3	30																
	2013	3	31																
Summary							1.00		2.5										

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*Ground Cover: 1=Grass; 2=Fallow; 3=Bare Ground; 4=Brome grass; 5=Sod; 6=Straw mulch; 7=Grass muck; 8=Bare muck; 0=Unknown
"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
"A" values in the Precipitation Flag or the Snow Flag column indicate a multiday total, accumulated since last measurement, is being used.
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04/05/2014

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www.ncdc.noaa.gov

Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F)			Precipitation(see **)					Evaporation		Soil Temperature (°F)					
				24 hrs. ending at observation time		at Observation	24 Hour Amounts ending at observation time				At Obs Time			4 in depth			8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	4	1																
	2013	4	2																
	2013	4	3																
	2013	4	4																
	2013	4	5																
	2013	4	6																
	2013	4	7																
	2013	4	8																
	2013	4	9																
	2013	4	10																
	2013	4	11																
	2013	4	12																
	2013	4	13																
	2013	4	14																
	2013	4	15																
	2013	4	16																
	2013	4	17																
	2013	4	18																
	2013	4	19																
	2013	4	20																
	2013	4	21																
	2013	4	22																
	2013	4	23				0.00		0.0										
	2013	4	24				0.00		0.0										
	2013	4	25				0.00		0.0										
	2013	4	26				0.00		0.0										
	2013	4	27				0.00		0.0										
	2013	4	28				0.00		0.0										
	2013	4	29				0.09												
	2013	4	30				0.29												
Summary							0.38		0.0										

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"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
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04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time		Temperature (°F) at Observation	Precipitation(see **) 24 Hour Amounts ending at observation time				Precipitation At Obs Time	Evaporation		Soil Temperature (°F) 4 in depth			Soil Temperature (°F) 8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	5	1				0.06												
	2013	5	2				0.00		0.0										
	2013	5	3				0.00		0.0										
	2013	5	4				0.00		0.0										
	2013	5	5				0.00		0.0										
	2013	5	6				0.00		0.0										
	2013	5	7				0.01												
	2013	5	8				0.87												
	2013	5	9				0.05												
	2013	5	10				0.04												
	2013	5	11				0.50												
	2013	5	12				0.74												
	2013	5	13				0.00		0.0										
	2013	5	14				0.00		0.0										
	2013	5	15				0.00		0.0										
	2013	5	16				0.00		0.0										
	2013	5	17				0.00		0.0										
	2013	5	18				0.00		0.0										
	2013	5	19				0.02												
	2013	5	20				0.06												
	2013	5	21																
	2013	5	22																
	2013	5	23																
	2013	5	24																
	2013	5	25																
	2013	5	26																
	2013	5	27																
	2013	5	28																
	2013	5	29																
	2013	5	30																
	2013	5	31																
Summary							2.35		0.0										

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"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
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03/04/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown   Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Evaporation Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	4 in depth Max.	4 in depth Min.	8 in depth Ground Cover (see *)	8 in depth Max.	8 in depth Min.
	2013	6	1																
	2013	6	2																
	2013	6	3																
	2013	6	4																
	2013	6	5																
	2013	6	6																
	2013	6	7				1.75												
	2013	6	8				0.82												
	2013	6	9				0.01												
	2013	6	10				0.53												
	2013	6	11				1.33												
	2013	6	12				0.01												
	2013	6	13				T												
	2013	6	14				0.33												
	2013	6	15				0.01												
	2013	6	16				0.00		0.0										
	2013	6	17				T												
	2013	6	18				0.00		0.0										
	2013	6	19				0.11												
	2013	6	20				0.00		0.0										
	2013	6	21				0.00		0.0										
	2013	6	22				0.00		0.0										
	2013	6	23				T												
	2013	6	24				0.57												
	2013	6	25				0.01												
	2013	6	26				0.06												
	2013	6	27				0.25												
	2013	6	28				0.02												
	2013	6	29				0.31												
	2013	6	30				0.00		0.0										
Summary							6.12		0.0										

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"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
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04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F)			Precipitation(see **)					Evaporation		Soil Temperature (°F)					
				24 hrs. ending at observation time		at Observation	24 Hour Amounts ending at observation time				At Obs Time			4 in depth			8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	7	1				0.30												
	2013	7	2				0.18												
	2013	7	3				0.13												
	2013	7	4				1.12												
	2013	7	5				0.00		0.0										
	2013	7	6				0.00		0.0										
	2013	7	7				0.00		0.0										
	2013	7	8				0.19												
	2013	7	9				0.05												
	2013	7	10																
	2013	7	11																
	2013	7	12																
	2013	7	13																
	2013	7	14																
	2013	7	15																
	2013	7	16																
	2013	7	17																
	2013	7	18																
	2013	7	19																
	2013	7	20																
	2013	7	21																
	2013	7	22																
	2013	7	23																
	2013	7	24																
	2013	7	25																
	2013	7	26																
	2013	7	27																
	2013	7	28																
	2013	7	29																
	2013	7	30																
	2013	7	31																
Summary							1.97		0.0										

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time		Temperature (°F) at Observation	Precipitation(see **) 24 Hour Amounts ending at observation time				Precipitation At Obs Time	Evaporation		Soil Temperature (°F) 4 in depth			Soil Temperature (°F) 8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	8	1																
	2013	8	2																
	2013	8	3																
	2013	8	4																
	2013	8	5				0.00		0.0										
	2013	8	6				T												
	2013	8	7				0.03												
	2013	8	8				0.12												
	2013	8	9				0.05												
	2013	8	10				0.24												
	2013	8	11				0.01												
	2013	8	12				0.00		0.0										
	2013	8	13				T												
	2013	8	14				0.46												
	2013	8	15				0.00		0.0										
	2013	8	16				0.00		0.0										
	2013	8	17				0.00		0.0										
	2013	8	18				0.03												
	2013	8	19				0.04												
	2013	8	20				0.00		0.0										
	2013	8	21				0.00		0.0										
	2013	8	22				0.04												
	2013	8	23				0.00		0.0										
	2013	8	24				0.11												
	2013	8	25				0.00		0.0										
	2013	8	26				0.00		0.0										
	2013	8	27				0.00		0.0										
	2013	8	28				0.00		0.0										
	2013	8	29				0.35												
	2013	8	30				0.00		0.0										
	2013	8	31				0.00		0.0										
Summary							1.48		0.0										

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*Ground Cover: 1=Grass; 2=Fallow; 3=Bare Ground; 4=Brome grass; 5=Sod; 6=Straw mulch; 7=Grass muck; 8=Bare muck; 0=Unknown
"s" This data value failed one of NCDC's quality control tests.
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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown   Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

				Temperature (°F)			Precipitation(see **)					Evaporation		Soil Temperature (°F)					
				24 hrs. ending at observation time		at Observation	24 Hour Amounts ending at observation time				At Obs Time			4 in depth			8 in depth		
Preliminary	Year	Month	Day	Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	9	1				0.00		0.0										
	2013	9	2				0.10												
	2013	9	3				0.00		0.0										
	2013	9	4				0.00		0.0										
	2013	9	5				0.00		0.0										
	2013	9	6				0.00		0.0										
	2013	9	7																
	2013	9	8																
	2013	9	9																
	2013	9	10																
	2013	9	11																
	2013	9	12																
	2013	9	13																
	2013	9	14																
	2013	9	15																
	2013	9	16																
	2013	9	17																
	2013	9	18																
	2013	9	19																
	2013	9	20																
	2013	9	21																
	2013	9	22																
	2013	9	23																
	2013	9	24																
	2013	9	25																
	2013	9	26																
	2013	9	27																
	2013	9	28																
	2013	9	29																
	2013	9	30																
Summary							0.10		0.0										

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Empty, or blank, cells indicate that a data observation was not reported.
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"s" This data value failed one of NCDC's quality control tests.
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03/04/2014

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Record of Climatological Observations

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National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time Max.	Temperature (°F) 24 hrs. ending at observation time Min.	Temperature (°F) at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	At Obs Time Snow, ice pellets, hail, ice on ground (in)	Evaporation 24 Hour Wind Movement (mi)	Amount of Evap. (in)	Soil Temperature (°F) 4 in depth Ground Cover (see *)	Max.	Min.	8 in depth Ground Cover (see *)	Max.	Min.
	2013	10	1																
	2013	10	2				0.00		0.0										
	2013	10	3				0.00		0.0										
	2013	10	4				0.00		0.0										
	2013	10	5				0.00		0.0										
	2013	10	6				0.00		0.0										
	2013	10	7				0.00		0.0										
	2013	10	8				1.28												
	2013	10	9				0.00		0.0										
	2013	10	10				0.48												
	2013	10	11				1.47												
	2013	10	12				2.59												
	2013	10	13				0.24												
	2013	10	14				0.02												
	2013	10	15				0.00		0.0										
	2013	10	16				T												
	2013	10	17				0.00		0.0										
	2013	10	18				0.07												
	2013	10	19				0.00		0.0										
	2013	10	20				0.00		0.0										
	2013	10	21																
	2013	10	22																
	2013	10	23																
	2013	10	24																
	2013	10	25																
	2013	10	26																
	2013	10	27																
	2013	10	28																
	2013	10	29																
	2013	10	30																
	2013	10	31																
Summary							6.15		0.0										

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04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F)			Precipitation(see **)					Evaporation		Soil Temperature (°F)					
				24 hrs. ending at observation time		at Observation	24 Hour Amounts ending at observation time				At Obs Time			4 in depth			8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	11	1																
	2013	11	2																
	2013	11	3																
	2013	11	4																
	2013	11	5																
	2013	11	6																
	2013	11	7																
	2013	11	8																
	2013	11	9																
	2013	11	10																
	2013	11	11																
	2013	11	12																
	2013	11	13																
	2013	11	14																
	2013	11	15																
	2013	11	16																
	2013	11	17																
	2013	11	18																
	2013	11	19																
	2013	11	20																
	2013	11	21																
	2013	11	22																
	2013	11	23				0.00		0.0										
	2013	11	24				0.00		0.0										
	2013	11	25				0.00		0.0										
	2013	11	26				0.00		0.0										
	2013	11	27				2.28												
	2013	11	28				0.07												
	2013	11	29				0.00		0.0										
	2013	11	30				0.00		0.0										
Summary							2.35		0.0										

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04/05/2014

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Station: **SILVER SPRING 0.9 N, MD US**

GHCND:US1MDMG0052

Observation Time Temperature: Unknown   Observation Time Precipitation: Unknown

Elev: 361 ft. Lat: 39.027° N Lon: 77.022° W

Preliminary	Year	Month	Day	Temperature (°F) 24 hrs. ending at observation time		at Observation	Precipitation (see **) 24 Hour Amounts ending at observation time				At Obs Time	Evaporation		Soil Temperature (°F) 4 in depth			8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	Flag	Snow, ice pellets, hail (in)	Flag	Snow, ice pellets, hail, ice on ground (in)	24 Hour Wind Movement (mi)	Amount of Evap. (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.	Min.
	2013	12	1				0.00		0.0										
	2013	12	2				0.00		0.0										
	2013	12	3				0.00		0.0										
	2013	12	4				0.00		0.0										
	2013	12	5				0.00		0.0										
	2013	12	6				0.05												
	2013	12	7				1.14												
	2013	12	8				0.00		0.0										
	2013	12	9				1.10		1.2		1								
	2013	12	10				0.22		1.0		1								
	2013	12	11				0.08		1.1		2								
	2013	12	12				0.00		0.0		2								
	2013	12	13																
	2013	12	14																
	2013	12	15																
	2013	12	16																
	2013	12	17																
	2013	12	18																
	2013	12	19																
	2013	12	20																
	2013	12	21																
	2013	12	22																
	2013	12	23																
	2013	12	24																
	2013	12	25																
	2013	12	26																
	2013	12	27																
	2013	12	28																
	2013	12	29																
	2013	12	30																
	2013	12	31																
Summary							2.59		3.3										

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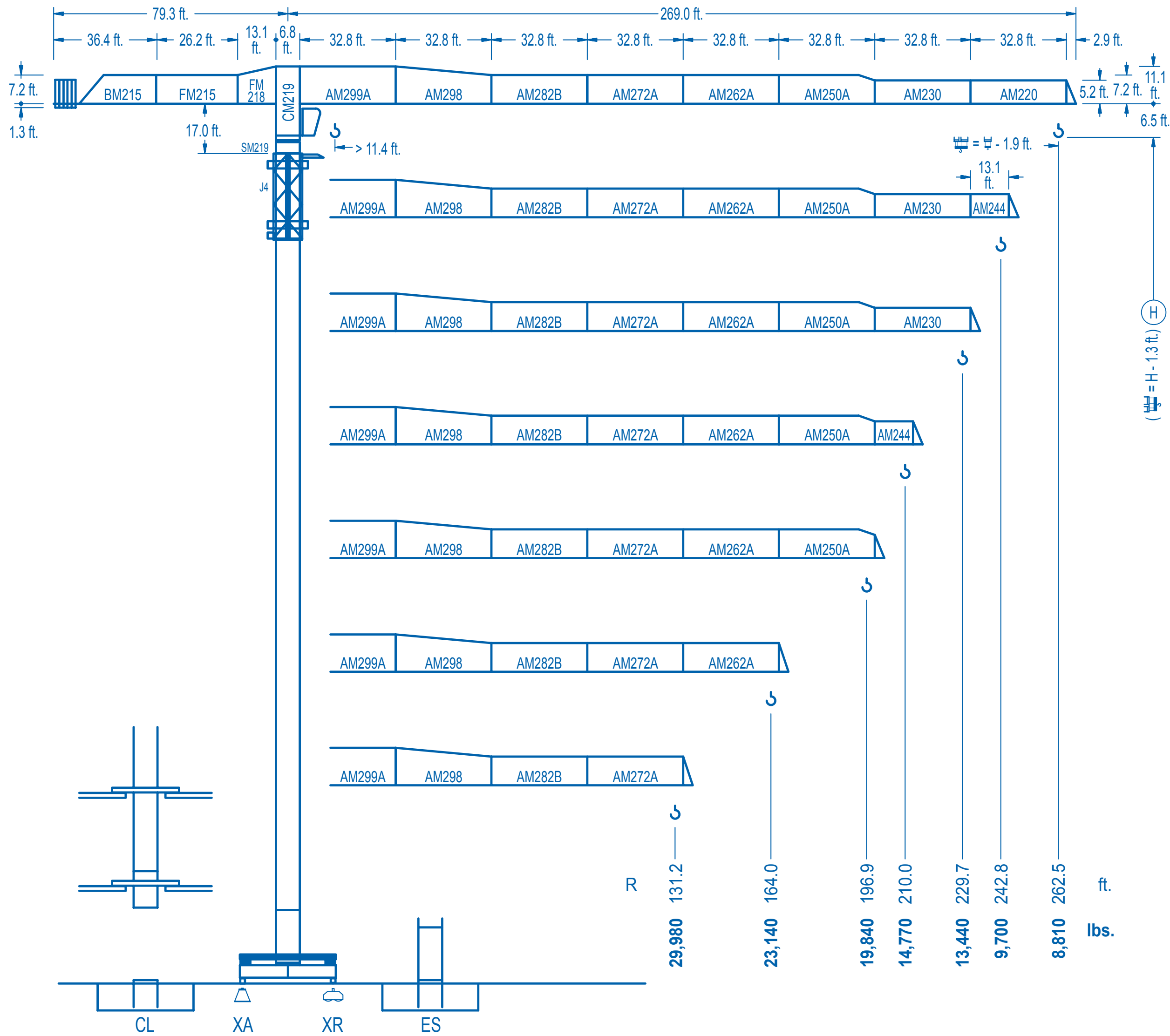
APPENDIX B. TOWER CRANE LOAD CHART

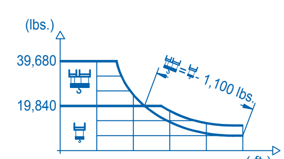
LINDEN COMANSA

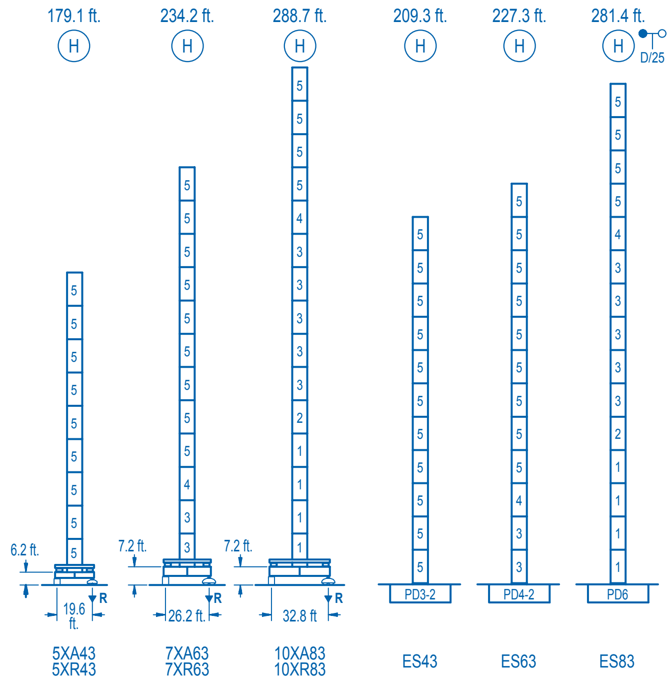
LC 2100 — 21 LC 550 — 39,680 lbs.

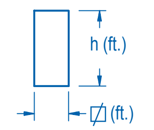


CE EN 14439 (C/25)

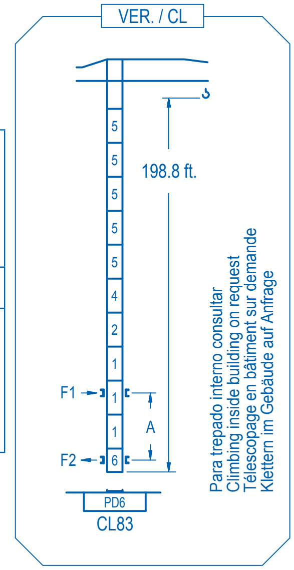
R (ft.)	4-fall				2-fall									
262.5	67.6 **39,680**	78.7 **33,450**	98.4 **25,900**	123.7 **19,840**	127.0 **19,840**	144.4 **17,250**	164.0 **14,980**	177.2 **13,750**	196.9 **12,230**	210.0 **11,370**	229.7 **10,270**	242.8 **9,640**	262.5 **8,810**	ft. **lbs.**
242.8	67.6 **39,680**	78.7 **33,440**	98.4 **25,890**	123.7 **19,840**	127.6 **19,840**	144.4 **17,330**	164.0 **15,060**	177.2 **13,830**	196.9 **12,300**	210.0 **11,440**	229.7 **10,330**	242.8 **9,700**	ft **lbs.**	
229.7		84.0 **39,680**	98.4 **33,140**	111.5 **28,750**	131.2 **23,870**	153.9 **19,840**	161.1 **19,840**	177.2 **17,890**	196.9 **15,930**	210.0 **14,840**	229.7 **13,440**	ft **lbs.**		
210.0		83.0 **39,680**	98.4 **32,810**	111.5 **28,470**	131.2 **23,630**	152.6 **19,840**	160.4 **19,840**	177.2 **17,790**	196.9 **15,860**	210.0 **14,770**	ft **lbs.**			
196.9			100.7 **39,680**	111.5 **35,370**	131.2 **29,470**	144.4 **26,460**	164.0 **22,870**	186.7 **19,840**	196.9 **19,840**	ft **lbs.**				
164.0			100.4 **39,680**	111.5 **35,270**	131.2 **29,390**	144.4 **26,380**	164.0 **23,140**	ft **lbs.**						
131.2			100.4 **39,680**	111.5 **35,310**	131.2 **29,980**	ft **lbs.**								

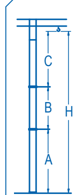






nº	Ref.	⌀	h
1	D36	8.2	18.0
2	TD36A	8.2	18.0
3	D34	8.2	18.0
4	TD34	8.2	18.0
5	D33	8.2	18.0
6	CLD36	8.2	12.4





	5XA43		7XA63		10XA83	
A max	132.5		187.6		242.1	
B max	-	108.3	-	108.3	-	108.3
C max	172.9	154.9	154.9	154.9	154.9	154.9
H max	305.4	395.7	342.5	450.8	397.0	505.2

	ES43		ES63		ES83	
A max	162.7		180.8		234.9	
B max	-	108.3	-	108.3	-	108.3
C max	154.9	154.9	154.9	154.9	154.9	154.9
H max	317.6	425.9	335.6	443.9	389.8	498.0

R. máx.	En servicio In operation En service In Betrieb	5XR43....282,190 lbs. 7XR63....266,540 lbs. 10XR83..272,490 lbs.

R. máx.	Fuera de servicio Out of service Hors service Ausser Betrieb	5XR43....201,500 lbs. 7XR63....252,650 lbs. 10XR83..424,390 lbs.

Para otras zonas de viento o alturas superiores consultar
For other wind zones or additional hook heights on request
Pour d'autres zones de vent ou des hauteurs supplémentaires sur demande
Für andere Windzonen oder weiteren Hakenhöhen auf Anfrage

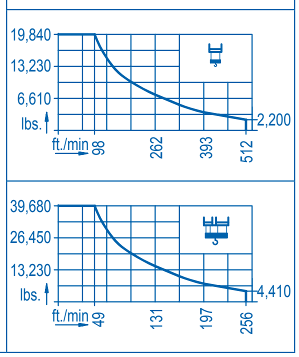
CFU-7.5
10 hp.
0 ⇨ 308 ft./min

GR-12
4 x 88 ft.lbs.
0 ⇨ 0.8 rpm

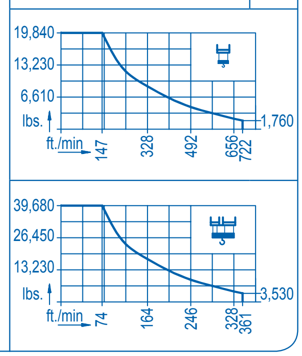
TRA-7.5	TRA-7.5
2 x 55 ft.lbs.	4 x 55 ft.lbs.
0 ⇨ 78 ft./min	
5XR43	7XR63 10XR83

* TRA-7.5VC	TRA-7.5VC
2 x 55 ft.lbs.	4 x 55 ft.lbs.
0 ⇨ 78 ft./min	
5XR43	7XR63 10XR83

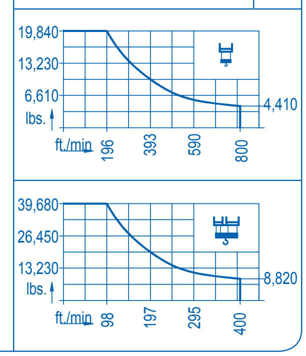
EFU5-50-45 — 2,590 ft — 67hp.



EFU6-65-45 * — 2,590 ft — 87 hp.



EFU4-110-45 * — 2,590 ft — 148 hp.



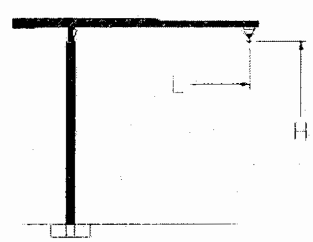
Tensión de alimentación Operating voltage Tension de service Betriebsspannung	480 V 3 ph 60 Hz

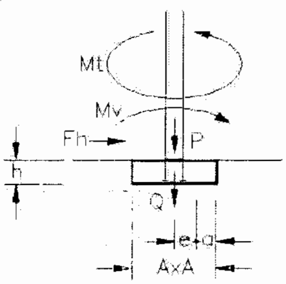
Opcional Optional En option Kaufoption	*

LINDEN COMANSA
Construcciones Metálicas COMANSA S. A.
Tel.: (34) 948 335 020
Fax: (34) 948 330 810
e-mail: info@comansa.com
www.comansa.com
Polígono Urbizkain
E-31620 HUARTE-PAMPLONA.- SPAIN

ES43

SR/DR 39,670 lbs.





$$e = \frac{Mv + Fh \times h}{P + Q} \leq \frac{A}{3}$$

$$\sigma t = \frac{2(P + Q)}{3 \times A \times a} \leq \sigma t_{adm}$$

Mt -Torsional moment. (x1000) ft.lbs.
Mv -Overturning moment. (x1000) ft.lbs.
P -Weight of crane (x1000) lbs.
Fh -Horizontal reaction (x1000) lbs.
Q -Mass of foundation concrete (x1000) lbs.
e -Excentricity
st -Pressure on ground
st_{adm} -Permissible ground pressure
L -Max. hook radius ft.
H -Hook height ft.
n -Number of sections
A -Foundation dimensions ft.

H (ft.)	n		IN SERVICE L (ft.) 262.4	242.7	229.6	209.9	196.8	164.0	131.2	OUT OF SERVICE L (ft.) 262.4	242.7	229.6	209.9	196.8	164.0	131.2
208.9	11	Mv	3,490	3,455	4,061	4,014	4,659	4,534	4,538	4,917	5,002	5,554	5,538	5,882	5,831	5,732
		Fh	9	9	9	9	10	10	10	43	47	31	31	31	30	30
		P	314	309	315	307	316	302	292	305	300	301	292	296	279	263
190.9	10	Mv	3,234	3,202	3,790	3,747	4,371	4,254	4,261	4,641	4,674	4,970	4,958	5,304	5,260	5,171
		Fh	9	9	9	9	9	9	9	29	29	29	28	28	28	27
		P	304	300	305	297	306	293	283	296	290	291	283	286	270	253
172.9	9	Mv	3,003	2,974	3,547	3,506	4,112	4,002	4,011	4,095	4,132	4,430	4,422	4,770	4,733	4,654
		Fh	8	8	8	8	8	8	8	26	26	26	26	26	26	25
		P	295	290	295	288	296	283	273	286	280	282	273	277	260	243
154.8	8	Mv	2,796	2,769	3,327	3,290	3,880	3,777	3,787	3,594	3,635	3,933	3,929	4,278	4,250	4,180
		Fh	7	7	7	7	7	7	7	24	24	24	24	24	23	22
		P	285	280	285	278	287	273	263	276	270	272	263	267	250	233
136.8	7	Mv	2,613	2,587	3,133	3,098	3,672	3,575	3,586	3,136	3,180	3,480	3,480	3,831	3,811	3,750
		Fh	7	7	7	7	7	7	7	22	22	21	21	21	21	20
		P	275	270	276	268	277	264	254	266	261	262	253	257	240	224
118.7	6	Mv	2,449	2,426	2,961	2,929	3,489	3,397	3,409	2,721	2,769	3,071	3,075	3,428	3,416	- 3,364
		Fh	6	6	6	6	6	6	6	19	19	19	19	19	18	18
		P	266	261	266	259	267	254	244	257	251	253	244	248	231	214
100.7	5	Mv	2,307	2,284	2,809	2,780	3,330	3,241	3,254	2,350	2,402	2,705	2,713	3,068	3,063	3,021
		Fh	5	5	5	5	5	5	5	17	17	16	16	16	16	15
		P	256	251	256	249	258	244	234	247	241	243	234	238	221	204
82.6	4	Mv	2,183	2,162	2,679	2,651	3,191	3,105	3,118	2,023	2,078	2,384	2,396	2,752	2,755	2,722
		Fh	5	5	5	5	5	5	5	14	14	14	14	14	13	13
		P	246	241	247	239	248	235	225	237	232	233	224	228	211	195
Mt			564	564	564	564	564	564	564	0	0	0	0	0	0	0

APPENDIX C. MARYLAND HAULING PERMIT REQUIREMENTS

Maryland Oversize/Overweight Hauling Permit Manual

Maryland State Highway Administration
Office of Traffic & Safety
Motor Carrier Division
Permit Manual as of April 10, 2008

HAULING PERMIT LOAD REQUIREMENTS

WIDTH

8 feet – 9 feet inch

- No notes required

11 feet 11 inches

- Wide Load Signs Required

12 feet – 13 feet

- Wide Load Signs required
- Beltway Hours – travel restrictions apply where applicable

13 feet 1 inch – 13 feet 11 inches

- Wide Load Signs Required
- Beltway Hours – travel restrictions apply
- (1) Special Escort (private) required (Exception – Mobile and Modular Homes)

14 feet

- Keep to the extreme right of roadway using the shoulder whenever possible
- Special Escorts required (2 private)
- Moves allowed 9 a.m.-3:30 p.m. only

16 feet

- SHA District Engineer approval required prior to move
- 48-Hour advance notice to the Maryland State Police prior to move – MSP escort required for any move
- Performance Bond required or Contractual Liability Clause required

HEIGHT

13 feet 6 inches

- Legal limit – no special conditions apply unless noted on the permit

13 feet 7 inches – 15 feet 5 inches

- Permittee responsible for over head clearance on all moves

14 feet 6 inches

- Height pole required

15 feet 6 inches

- Any trees to be trimmed must be cleared by the Department of Forest and Parks (410-255-0079)

16 feet or higher

- Approval of SHA District Engineer is required prior to any move
- MSP Escort required
- SHA Statewide Traffic Operations Center (SOC) must be notified prior to move
- Performance Bond or Contractual Liability Clause must be on file prior to the move to cover damages related to the move

LENGTH

55 feet

- No special notes or conditions required unless needed

85 feet 1 inch

- (1 private) Special Escort required

100 feet or longer

- Beltway Hours – travel restriction 9 a.m. to 3:30 p.m. only
- (1 private) Special Escort required
- Performance bond or Contractual Liability Clause must be on file prior to all moves to cover any damage associated with the move

120 feet or longer

- Beltway Hours – travel restriction 9 a.m. to 3:30 p.m. only
- Special Escort required
- Performance bond must be on file prior to all moves to cover any damages associated with the move
- 48-Hour notice must be given prior to the move

140 feet or longer

- Two Special Escorts required
- SHA District Engineer approval required prior to all moves
- Beltway Hours – travel restriction 9 a.m. to 3:30 p.m. only
- 48-Hour notice must be given prior to the move

STEEL BEAM REQUIREMENTS –

70 feet long not including the tractor-trailer

- No permit required
- Travel during daylight hours only

WEIGHT

Over 45 tons

- Beltway hours – travel restriction 9 a.m. to 3:30 p.m. only
- Must maintain speed limit
- For axle weight restrictions, call the HPU for additional requirements

Over 60 Tons

- (1) Special Escort required
- MSP Escort required
- SHA Office of Bridge approval required if load is a self propelled unit or does not meet the axle weight and space requirements for combination vehicles
- Permit vehicle must maintain a speed 10 mph under the posted speed limit
- Moves allowed 9 a.m. to 3:30 p.m. only
- Special Escorts and 1 MSP escort vehicle is required if load is going against traffic
- Performance bond or Contractual Liability Clause must be on file
- Combination vehicle loads up to but not exceeding 150,000 allowed on Interstate routes only (does not need to go to SHA Office of Bridge Development)

APPENDIX D. TRUCKING TRANSPORTATION COST

The outlook for 2012 points to a continued increase in industry costs. The two key cost centers, fuel and driver wages, are expected to increase in 2012. Fuel prices have risen nearly 10 percent in the first eight months of 2012, which will almost certainly increase multiple cost centers, including (petroleum-based) tire purchases. For driver wages, the truck driver shortage is expected to become increasingly worse over time, likely translating to higher wages and higher industry costs. According to ATRI's 2011 "Top Industry Issues" survey of industry stakeholders,[2] the driver shortage and fuel costs ranked third and fifth on the list, respectively. The driver shortage issue rose from number five in 2010 to number three in 2011, indicating that the economy was improving. Other factors are likely amplifying the shortage however, including an aging workforce, new government regulations and driver quality-of-life challenges.

Table ES1. Average Carrier Costs per Mile, 2008, 2009, 2010 and 2011

Motor Carrier Costs	2008	2009	2010	2011
Vehicle-based				
Fuel & Oil Costs	$0.633	$0.405	$0.486	$0.590
Truck/Trailer Lease or Purchase Payments	$0.213	$0.257	$0.184	$0.189
Repair & Maintenance	$0.103	$0.123	$0.124	$0.152
Truck Insurance Premiums	$0.055	$0.054	$0.059	$0.067
Permits and Licenses	$0.016	$0.029	$0.040	$0.038
Tires	$0.030	$0.029	$0.035	$0.042
Tolls	$0.024	$0.024	$0.012	$0.017
Driver-based				
Driver Wages	$0.435	$0.403	$0.446	$0.460
Driver Benefits	$0.144	$0.128	$0.162	$0.151
TOTAL*	**$1.653**	**$1.451**	**$1.548**	**$1.706**

Table ES2. Average Carrier Costs per Hour, 2008, 2009, 2010 and 2011

Motor Carrier Costs	2008	2009	2010	2011
Vehicle-based				
Fuel & Oil Costs	$25.30	$16.17	$19.41	$23.58
Truck/Trailer Lease or Purchase Payments	$8.52	$10.28	$7.37	$7.55
Repair & Maintenance	$4.11	$4.90	$4.97	$6.07
Truck Insurance Premiums	$2.22	$2.15	$2.35	$2.67
Permits and Licenses	$0.62	$1.15	$1.60	$1.53
Tires	$1.20	$1.14	$1.42	$1.67
Tolls	$0.95	$0.98	$0.49	$0.69
Driver-based				
Driver Wages	$17.38	$16.12	$17.83	$18.39
Driver Benefits	$5.77	$5.11	$6.47	$6.05
TOTAL*	**$66.07**	**$58.00**	**$61.91**	**$68.21**

[2] Critical Issues in the Trucking Industry – 2011. ATRI. Arlington, VA. 2011.

* Line items may not sum to total shown due to rounding.

APPENDIX E. MODULARIZATION GENERAL CONDITIONS SAVINGS

REVISED GENERAL CONDITIONS							
					Material		
Cost Code		Description	Qty.	Units	Per Unit	Total	Total
01 30 00	ADMINISTRATIVE REQUIREMENTS						
	01 31 00	PROJECT MANAGEMENT AND COORDINATION					
		OFFICE SUPPLIES & EQUIPMENT	19	Months	$500.00	$9,500.00	$9,500.00
		OFFICE FURNITURE	19	Months	$400.00	$7,600.00	$7,600.00
		PRINTING DRAWING/SPECIFICATIONS	19	Months	$300.00	$5,700.00	$5,700.00
		FAX MACHINE	19	Months	$200.00	$4,000.00	$4,000.00
		POSTAGE/PACKAGING	19	Months	$400.00	$7,600.00	$7,600.00
		COMPUTER EQUIPMENT/SOFTWARE	19	Months	$100.00	$1,900.00	$1,900.00
		OX BLUE WEBCAM	19	Months	$200.00	$3,800.00	$3,800.00
		TOTAL					$40,100.00
01 40 00	QUALITY REQUIREMENTS						
	01 45 00	QUALITY CONTROL					
		TESTING AND INSPECTION	1	LS	$20,000.00	$20,000.00	$20,000.00
		CONSULTANTS	1	LS	$40,000.00	$40,000.00	$40,000.00
		TOTAL					$60,000.00
01 50 00	TEMPORARY FACILITIES AND CONTROLS						
	01 51 00	TEMPORARY UTILITIES CONSUMPTION	19	Months	$4,000.00	$76,000.00	$76,000.00
	01 52 00	CONSTRUCTION FACILITIES					
		JOB OFFICE/TRAILER	14	Months	$900.00	$12,600.00	$12,600.00
		STORAGE TRAILER	19	Months	$300.00	$5,700.00	$5,700.00
		TOILETS	19	Months	$500.00	$9,500.00	$9,500.00
		DRINKING WATER/ICE	19	Months	$100.00	$1,900.00	$1,900.00
		RADIOS/PHONES	19	Months	$300.00	$5,700.00	$5,700.00
	01 54 00	CONSTRUCITON AIDS					
		PERSONAL PROTECTIVE EQUIPMENT	19	Months	$100.00	$1,900.00	$1,900.00
		TEMPORARY HOISTS / FORKLIFT	19	Months	$1,000.00	$19,000.00	$19,000.00
		TEMPORARY CRANES	INCLUDED UNDER GMP				
	01 55 00	VEHICULAR ACCESS AND PARKING					
		TEMPORARY STONE SITE ROADS	INCLUDED IN THE SITEWORK SCOPE				
	01 56 00	TEMPORARY BARRIERS AND ENCLOSURES					
		TEMPORARY FENCING	INCLUDED UNDER GMP				
	01 57 00	TEMPORARY CONTROLS					
		TEMPORARY EROSION AND SEDIMENT CONTROL	INCLUDED IN THE SITEWORK SCOPE				
		TOTAL					$132,300.00
01 70 00	EXECUTION AND CLOSEOUT REQUIREMENTS						
	01 73 00	EXECUTION					
		SIGNAGE	19	Month	$50.00	$950.00	$950.00
		AUTO ALLOWANCES	19	Month	$4,000.00	$76,000.00	$76,000.00
	01 74 00	CLEANING AND WASTE MANAGEMENT					
		DUMPSTERS	19	Months	$5,000.00	$95,000.00	$95,000.00
		AS NECESSARY & FINAL CLEANING	INCLUDED IN THE CLEANERS SCOPE				
		Total					$171,950.00

REVISED GENERAL CONDITIONS & STAFF TOTAL					
Description	**Quantity**	**Units**	**Labor $/Unit**	**Labor Total**	**Grand Total**
Personnel/Staffing					
Dave Tapparo, Vice President	4	Months	$120.00	$76,800.00	$76,800.00
Tommy Rumley, Project Executive	19	Months	$98.00	$297,920.00	$297,920.00
Mark Metzler, Project Manager	19	Months	$75.00	$228,000.00	$228,000.00
John Aldridge, Superintendent	19	Months	$98.00	$297,920.00	$297,920.00
Charlie Liesfeld, Assistant Superintendent	19	Months	$65.00	$197,600.00	$197,600.00
Will Thomas, Assistant Superintendent	9	Months	$65.00	$93,600.00	$93,600.00
Mike Ogrady, Assistant Superintendent	9	Months	$65.00	$93,600.00	$93,600.00
Brian LeTard, Safety Manager	2	Months	$65.00	$20,800.00	$20,800.00
Clerical	2	Months	$45.00	$14,400.00	$14,400.00
Kevin Martyn, Field Engineer Intern	3	Months	$18.00	$8,640.00	$8,640.00
Total Staff Requirements					$1,329,280.00
Administrative Requirements					$40,100.00
Quality Requirements					$60,000.00
Temporary Facilities and Controls					$132,300.00
Executions and Closeout Requirements					$171,950.00
BASELINE TOTAL GENERAL CONDITIONS AND FEE					**$1,733,630.00**

Modularization General Conditions Savings			
Catgory	ACTUAL GENERAL CONDITIONS (21 MONTHS)	REVISED SCHEDULE (19 MONTHS)	Savings
Total Staff Requirements	$1,476,800.00	$1,329,280.00	**$147,520.00**
Administrative Requirements	$43,900.00	$40,100.00	**$3,800.00**
Quality Requirements	$60,000.00	$60,000.00	**$0.00**
Temporary Facilities and Controls	$124,900.00	$132,300.00	**-$7,400.00**
Executions and Closeout Requirements	$190,050.00	$171,950.00	**$18,100.00**
Totals	$1,895,650.00	$1,733,630.00	**$162,020.00**
Percent Reduction			**9%**