Construction Management Depth Analysis

Prefabricated Exterior Panels: Construction Sequence, Cost, and Schedule Impacts

Background Information

The exterior walls for Campus Square were constructed implementing a 4.5" masonry brick veneer with metal stud backing. The exterior walls were all constructed on-site over the course of approximately 11 weeks, including the curtain wall systems. The exterior masonry veneer took longer to complete than the original proposed duration of four weeks, which lengthened the overall duration of the project.

During preconstruction, Wohlsen Construction along with GreenWorks Development had initially proposed implementing a pre-fabricated wall system in order to accelerate the schedule. However, this idea was value engineered out early in the conceptualization of Campus Square due to the lack of tenant interest at the time, and associated costs of prefabrication.

Figure 10 –Installation of the Exterior Wall System
Image provided by Wohlsen Construction

Goal

If GreenWorks Development was able to secure tenants for Campus Square early in the preconstruction phase of the project, a prefabricated system could have been ideal in order to accelerate the schedule, and begin leasing out the building. The goal of this analysis is to determine the construction schedule and cost impacts of implementing a prefabricated exterior wall system on the Campus Square project.

Methods

- Consult with manufacturers of prefabricated wall systems to determine appropriate systems which may apply to Campus Square.

- Consult with Wohlsen Construction project manager for construction sequence considerations and cost impacts, as well as feasibility of proposed system.
- Determine cost impacts to General Conditions and building shell
- Determine construction sequence changes, and project duration changes
- Develop new construction schedule and costs analysis for the proposed prefabricated system

Resources

- TEAM Panels International
- KERR Interior Systems Ltd. & Composite Building Systems Inc.
- Manitex Crane Guide
- Wohlsen Construction
- Microsoft Project
- R.S. Means Cost Data

Expected Outcome

By implementing a prefabricated system for the façade of the building, I expect an accelerated enclosure duration once the superstructure is erected. Furthermore, the prefabricated system will allow for interior work to commence sooner due to the envelope of the building being completed sooner. However, this method will result in a higher CSF for the prefabricated wall assemblies, and will also result in a crane needed onsite to erect the panels. Overall, the wall panels will have a higher direct cost than the method implemented, however savings will occur in General Conditions costs, as well as schedule duration.

Actual Construction Sequence

Construction of the exterior façade was conducted entirely onsite. The sequence implemented, following the completion of the superstructure and cast-in-place concrete decks, was to essentially install each material used in the exterior wall assembly by wall face. Lifts were used in installing framing, sheathing and windows, which were followed with an adjustable scaffolding system during the brick veneer installation. Figure 11 below depicts the exterior façade during construction.

Figure 11-Exterior Façade Construction
Image provided by Wohlsen Construction

Scaffolding was erected, beginning with the west elevation, continuing counter-clockwise around the building. However, the east face of the building was left incomplete to allow for material access locations until enough material was stockpiled to complete the interior of the building. The brick veneer took approximately 8 weeks to complete, and the entire building shell was completed in approximately 3.5 months. A scaffolding sequence plan for the brick façade can be seen in the Figure 12 below. The curtain wall system was completed a few weeks later in order to allow for additional material access areas to the upper floors, after the east wall was completed.

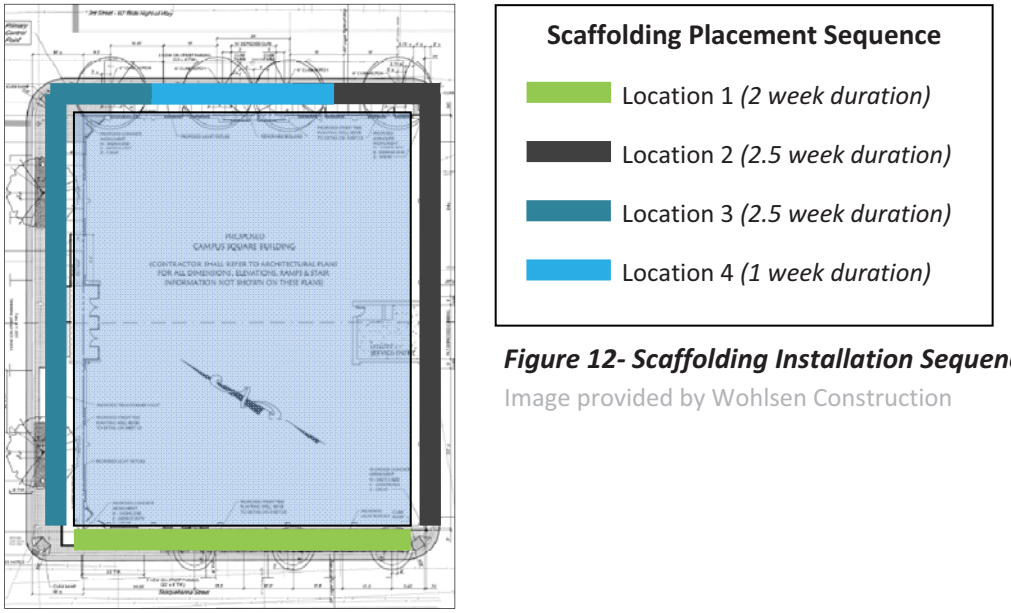


Figure 12- Scaffolding Installation Sequence
Image provided by Wohlsen Construction

Proposed Construction Sequence

For this analysis, interviews were conducted with TEAM Panels International and KERR Interior Systems Ltd. & Composite Building Systems Inc. (prefabrication manufacturers), as well as Wohlsen Construction, in order to formulate an appropriate construction sequence for the installation of the prefabricated wall panels.

The completed wall panels will be brought to the material storage and lay-down space located off of Susquehanna Street, south of the construction site. Once the superstructure is completed, and the slabs on deck are set, installation of the wall panels can begin. The panels will be loaded onto flatbed trailers at the storage locations, and then transported to the construction site in their appropriate sequence. For logistical simplicity, the 150-ton hydraulic truck crane used for steel erection will be implemented for the installation of the wall panels as well. The construction sequence used for the installation will be similar to the method used during the actual steel erection of Campus Square; where the on-site delivery rate of the panels will coincide with the daily installation rate for a crew. A crew can install approximately six wall panels per day, which includes attaching each wall panel to the superstructure of the building. Therefore, approximately four trailers will be required to make on-site deliveries of the

panels per work day. Additional time will be built into the schedule in order to allow for the multiple crane deployment locations.

Installation of the panels will begin on the northwest corner of Campus Square, working counterclockwise toward the northeast corner. Each wall will begin with the installation of the first floor panels, completing each floor before moving to the next. The tight confines of the site, as well as interference from existing overhead power lines, limit the ability of crane movement around the perimeter of the site. Figures 13 and 14 depict the panel installation sequence. A small amount of the exterior brick façade will need to be completed before the panels can be installed. This is due to the slope of the site, specifically located along the north, south, and west walls. The brick façade will need to be installed up to the base of the first floor base elevation marker; this work will be complete from October 8 through November 4 (additional time is permitted due to the critical path of the project).

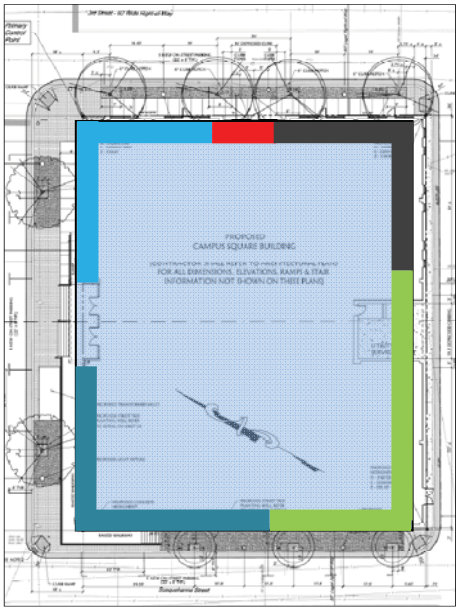


Figure 13-Panel Installation Sequence
Image provided by Wohlsen Construction

ID	Task Name	Duration
1	**Prefabricated Panels Installation**	**15 days**
2	Sequence 1- NW Corner	4 days
3	Crane Movement to Sequence 2	0.5 days
4	Sequence 2- SW Corner	4 days
5	Crane Movement to Sequence 3	0.5 days
6	Sequence 3- SE Corner	3 days
7	Crane Movement to Sequence 4	0.5 days
8	Sequence 4- NE Corner	4 days

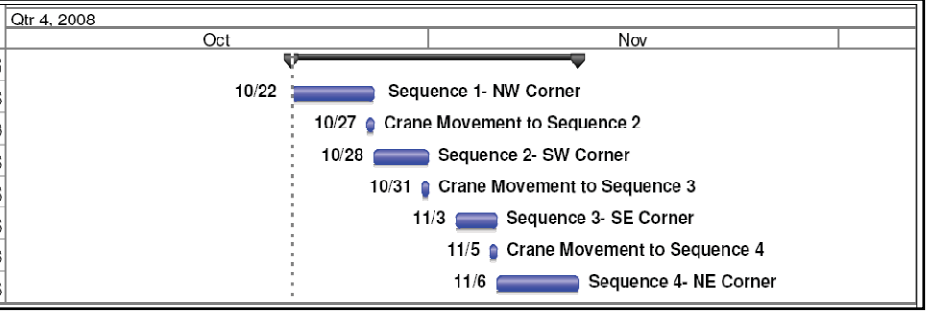


Figure 14- Panel Installation Schedule
Image provided by Wohlsen Construction

The following figures highlight each of the prefabricated panels to be installed, as well as coinciding sequence number. The red box indicates an area of Campus Square which will not be prefabricated, and will require on-site construction. This particular location, as with any red boxed area in the following figures, indicates construction entrances and/or areas of on-site construction unless otherwise noted.

The north wall will also require a unique installation sequence due to the presence of the three story curtain wall system, as well as multiple construction entrance locations. The panels will be installed in the sequence listed below in Figures 15, leaving an opening at the location of the curtain wall system on all three floors. This opening will also act as another construction material access location for the upper floors until the curtain wall system is installed after the completion of sequence 4. Once the curtain wall system is complete, the building envelope will be essentially complete besides the access areas on the east side. After sequence 4 is complete, interior work may begin.

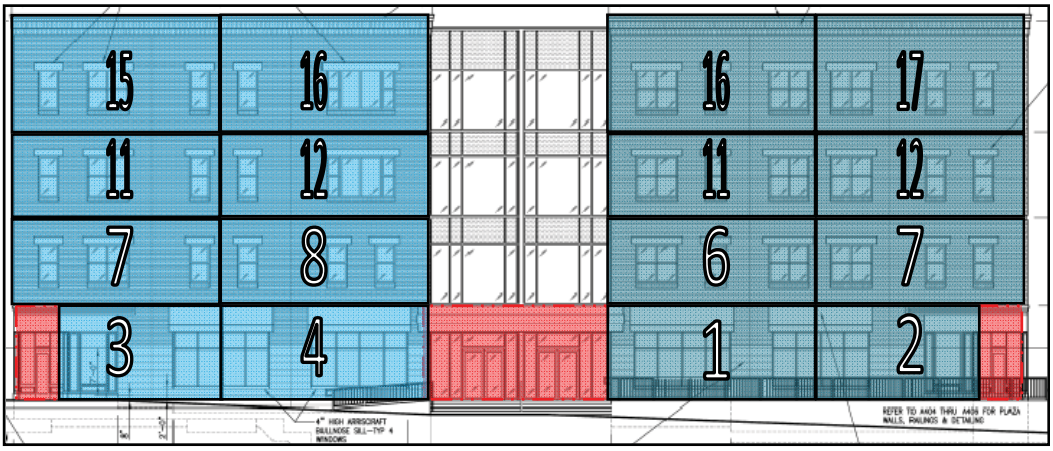


Figure 15- North Elevation: Panel Sequences 1&4

Image provided by Wohlsen Construction

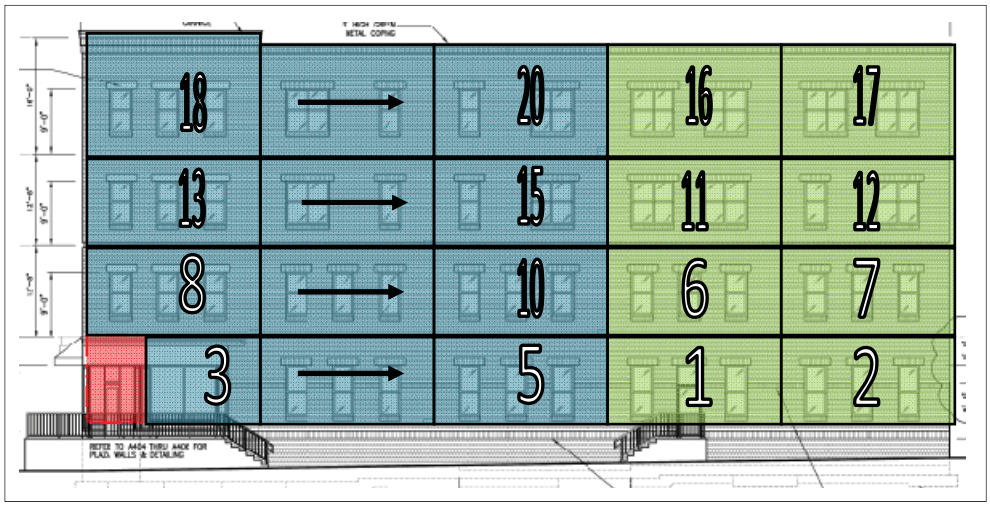


Figure 16-West Elevation: Panel Sequences 1 & 2

Image provided by Wohlsen Construction

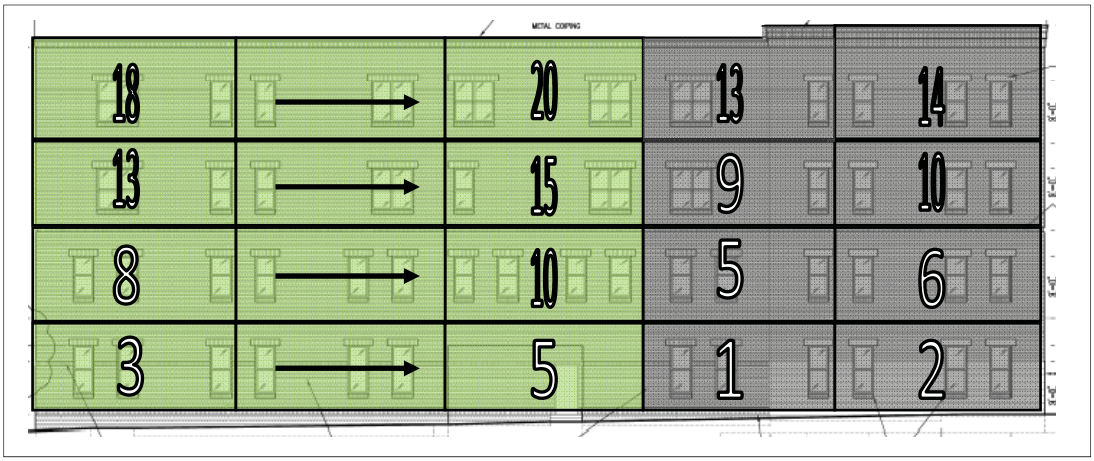


Figure 17- South Elevation: Panel Sequences 2 & 3
Image provided by Wohlsen Construction

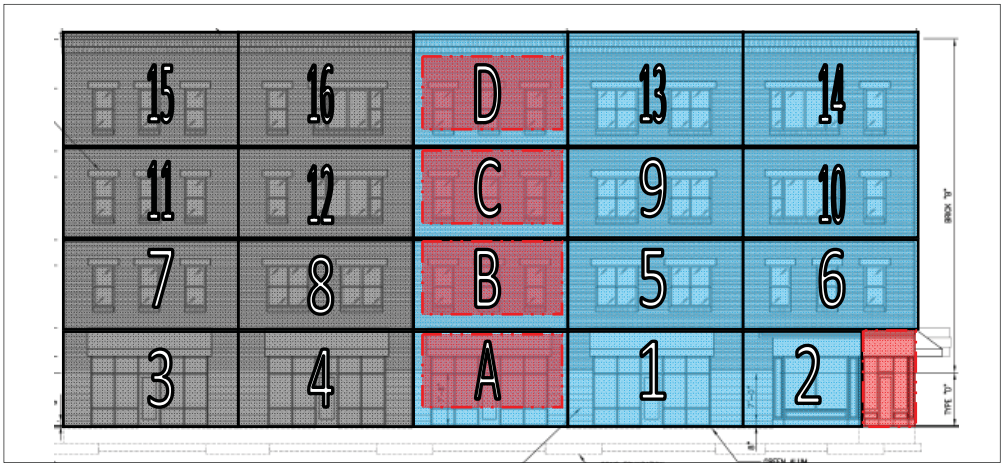


Figure 18- East Elevation: Panel Sequences 3,4,&5
Image provided by Wohlsen Construction

Installation of the east elevation will require additional coordination during construction. This wall will have construction entrances for materials along each floor. Panels 'A' through 'D' will not be installed in the same instances as the other wall faces. Instead, these particular panels will be stored in the material storage locations, and will be installed during sequence 5, once all appropriate interior materials have been delivered within the building. The locations of these openings mimic the construction methods used for Campus Square during the exterior façade installation. This concept can be better observed in Figure 19 on the following page.

Figure 19-East Elevation Construction Entrance Locations
Image provided by Wohlsen Construction

The 150-ton truck crane will be deployed in four locations during the installation of the panels; this is due to the limited mobility the crane has within the confines of the site. The crane will be located at the four corners of Campus Square based upon which sequence is currently being executed. Figure 20 below depicts the placement of the cranes, as well as delivery points for the panels.

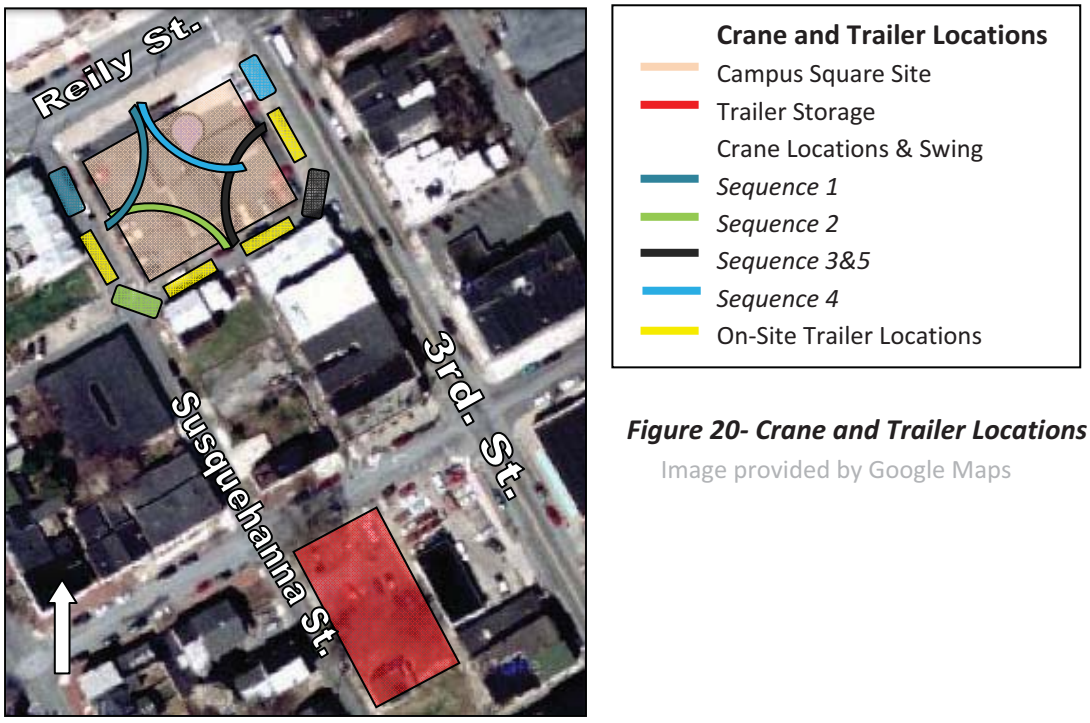


Figure 20- Crane and Trailer Locations
Image provided by Google Maps

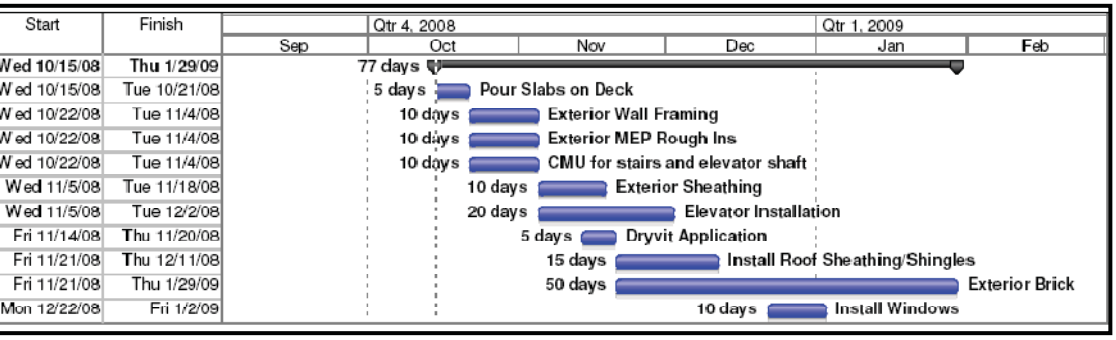
Vehicular traffic will need to be limited along streets when a panel sequence is being conducted. The most critical of the adjacent roads to Campus Square are Reily Street and 3rd Street due to their heavy

traffic patterns. During Steel erection, it was possible to keep all directions of traffic active; however, with the limited mobility once steel is erected, it will be necessary to close the sections of road the crane is on. Fortunately, Reily Street will be able to remain open at all times because no crane is ever placed on that road due to the existing overhead power lines limiting the crane swing.

Schedule Impact

The construction duration of the building shell will be substantially modified in order to compensate for the prefabricated panels. Overall, the building's shell construction duration will be shortened by approximately 6 weeks. This reduction can be attributed to the lack of on-site exterior wall construction, as well as earlier start times for related activities. Furthermore, the prefabricated panels will result in an earlier start time for interior work to begin because the building envelope will be secured earlier than the original construction duration. Figure 21 below compares the building shell phases of construction for the original construction schedule with the proposed methods. Having the building secure, and envelope complete, is perhaps the most important milestone change when compared to the original schedule because it allows for interior work to begin which encompasses the majority of construction time.

ID	Task Name	Duration	Start	Finish
1	**As-Built Building Shell**	**77 days**	**Wed 10/15/08**	**Thu 1/29/09**
2	Pour Slabs on Deck	5 days	Wed 10/15/08	Tue 10/21/08
3	Exterior Wall Framing	10 days	Wed 10/22/08	Tue 11/4/08
4	Exterior MEP Rough Ins	10 days	Wed 10/22/08	Tue 11/4/08
5	CMU for stairs and elevator	10 days	Wed 10/22/08	Tue 11/4/08
6	Exterior Sheathing	10 days	Wed 11/5/08	Tue 11/18/08
7	Elevator Installation	20 days	Wed 11/5/08	Tue 12/2/08
8	Dryvit Application	5 days	Fri 11/14/08	Thu 11/20/08
9	Install Roof Sheathing/Shin	15 days	Fri 11/21/08	Thu 12/11/08
10	Exterior Brick	50 days	Fri 11/21/08	Thu 1/29/09
11	Install Windows	10 days	Mon 12/22/08	Fri 1/2/09



ID	Task Name	Duration	Start	Finish
1	**Proposed Building Shell**	**45 days**	**Fri 8/1/08**	**Thu 10/2/08**
2	Exterior MEP Rough Ins	10 days	Fri 8/1/08	Thu 8/14/08
3	Pour Slabs on Deck	5 days	Fri 8/15/08	Thu 8/21/08
4	Install Roof Sheathing/Shingles	15 days	Fri 8/22/08	Thu 9/11/08
5	Pre-Fab. Panels Instal.	15 days	Fri 8/22/08	Thu 9/11/08
6	CMU for stairs and elevator shaft	10 days	Fri 8/22/08	Thu 9/4/08
7	Elevator Instal.	20 days	Fri 9/5/08	Thu 10/2/08
8	Curtain Wall Installation	5 days	Fri 9/12/08	Thu 9/18/08

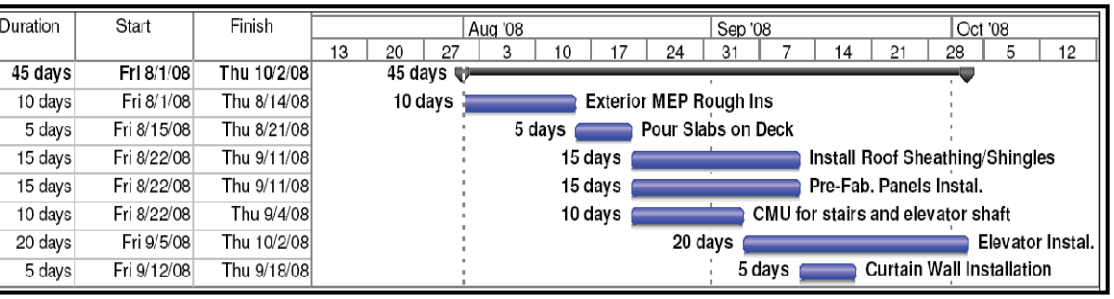


Figure 21- As-Built vs. Prefabrication Building Shell Schedule

Implementing the proposed construction sequence for the prefabricated wall panels will ideally reduce the overall construction schedule by approximately 9 weeks. The shortened schedule reflects time saved from the building shell phase, through the end of the project due to earlier activity start times when compared to the original schedule. Modifications to the schedule can also be seen with the inclusion of on-site masonry which will need to be performed before the first floor panels can begin. For the complete project schedule, see Appendix A of this report.

In comparing the reduction in preconstruction time with the original schedule, it is somewhat difficult to convey how much time will truly be reduced. Campus Square was not mobilized until nearly a year after preconstruction efforts began, mainly due to the owner's decision to delay construction due to the lack of tenant interest. Ideally, a preconstruction time of three to six months could have been achieved if anchor tenants were secured early into the building's conception and design. TEAM Panels suggested a conservative manufacturing time of approximately eight to ten panels could be constructed each day, following a design duration of a few weeks. Therefore, a reasonable preconstruction/procurement time for the 76 panels needed would be approximately seven weeks, including design.

Cost Impacts

The basis of implementation of the prefabricated wall panels would weigh entirely on an early tenant interest, which would make the high upfront costs of prefabrication more financially feasible due to an earlier payback duration.

The direct construction cost savings can be seen primarily in general conditions, specifically Wohlsen staffing costs. Overall, a general conditions savings of $154,691 will be achieved due to the reduced schedule duration. Figure 22 below compares the original general conditions with the proposed schedule duration. The complete general conditions comparison table may be found in Appendix B of this report.

General Conditions Estimate	
Description	**Cost**
Staffing	$693,730
Administrative Facilities and Supplies	$50,150
Safety	$7,000
Cleanup	$129,255
Jobsite Work Requirements	$144,450
Permitting	$66,686
Bonds and Insurance	$105,488
Total General Conditions Cost	**$1,196,759**

Proposed General Conditions Estimate	
Description	**Cost**
Staffing	$589,671
Administrative Facilities and Supplies	$43,150
Safety	$4,400
Cleanup	$106,324
Jobsite Work Requirements	$126,350
Permitting	$66,686
Bonds and Insurance	$105,488
Total General Conditions Cost	**$1,042,069**

Figure 22- As-Built vs. Prefabrication General Conditions Costs

Substituting the as-built exterior walls for the prefabricated panels will result in a direct cost increase of approximately $585,200. The increase in cost is due to high square foot costs associated with manufacturing and installing the panels, as well as the requirement of a large crane on-site during installation. Figure 23 on the following page compares the as-built exterior wall construction costs with

the proposed panel system. Cost values were compiled with the assistance of Wohlsen Construction and TEAM Panels.

As-Built Costs (Includes Installation)	
Exterior Wall Assembly	$ 600,000
Pella® Windows	$ 80,000
TOTAL	**$ 680,000**
SF COSTS	**$ 25.56**

Prefabrication Costs			
	Unit Cost (SF)	Installation Cost (SF)	Cost
Prefabricated Panels	$ 37	$ 10	$ 1,250,200
	Unit Cost (WK)	Duration (WK)	Cost
Truck Crane Costs	$ 5,000	3	$ 15,000
	Panel SF (Approx.)	**TOTAL**	**$ 1,265,200.00**
	26600	**SF COST**	**$ 47.56**

Figure 23- As-Built vs. Prefabrication Construction Costs

Overall, the prefabricated exterior wall panels will result in a substantially higher square foot (SF) cost for the building shell; however, the higher upfront costs would be mitigated by the overall strategy of a faster construction schedule.

Conclusions and Recommendation

The proposed construction sequence has several distinct advantages over the actual construction sequence implemented during the construction of the building shell of Campus Square. First, reducing the project duration reduces Wohlsen Construction's risk on the project, including risk of accidents and construction delays. Furthermore, the construction method decreases the amount of craftsmen on-site during active construction which reduces safety risk, as well as eliminates the need of exterior scaffolding during the installation of the brick veneer. Second, the proposed sequence allows the building shell to be completed approximately 6 weeks earlier, securing the exterior envelope, which enables the interior work to begin earlier. Most importantly, the time saved during preconstruction, as well as the earlier completion date, allows GreenWorks Development to begin leasing the spaces in order to begin profiting from their investment.

Although the prefabrication does have many benefits in delivering a faster, more quality building, it does come with problematic logistical and financial hurdles. The proposed construction sequence does require a crane to remain on-site past the steel erection phase. Additionally, the crane must move

multiple times during the panel installation, working around tight site confines, as well as overhead power lines. These added mobility limitations increase the possibility of accidents, or other construction related damages. Throughout the installation of the panels, a high degree of logistical and safety planning must be implemented in order to ensure the safety of the public, as well as the construction workers.

The most significant of the disadvantages related to the proposed methods, is the substantially higher upfront cost for the prefabricated panels. The total cost addition for the prefabricated system will be approximately $1,110,509, which is $430,509 higher than the original. This cost includes the general conditions reduction, and reflects the time savings during construction. It is important to note that the concept behind implementing the proposed methods would only occur if GreenWorks were able to secure tenants early during conceptualization/preconstruction, and required an accelerated construction schedule.

Prefabrication is an excellent strategy in order to reduce construction duration, and deliver a higher quality building due to the ability to control construction environments during manufacturing. Although the method does come with a higher price tag, as well as safety considerations due to the confines of the site, prefabrication would be a successful and profitable alternative for GreenWorks to implement in order to quickly construct and lease out Campus Square.