

# III. Curtain Wall Prefabrication Analysis (Construction Depth)

## *Introduction*

During the PACE Seminar in 2008, the topic of prefabrication was brought up for discussion. It was mentioned that because of where the construction industry was headed, prefabrication would become more prevalent. This was so for several reasons. The economy's condition was and still is resulting in diminishing job opportunities throughout many industries including construction. Therefore, fewer laborers would be available to perform certain tasks on the job site. Architects are developing more involved designs for their projects, which require higher quality control for the finished product. Finally, time is becoming ever more sensitive. Where time can be conserved, money can be saved as well. Prefabrication provides the opportunity to accomplish these requirements in a demanding industry such as construction.

## **Problem Statement**

Main & Gervais is a sixteen-story office building located in Columbia, South Carolina. At this geographical location, unions are not that prevalent. This fact results in cheaper labor and the ability to combine tasks so the output from laborers is maximized. For Main & Gervais, it has an aluminum curtain wall system as its façade. The chosen way for construction of the curtain wall is the stick-built method. The stick-built method has a few disadvantages attached to it including a messier site, lower quality control, and a slower process. The one main advantage it does have is the potential for cheaper labor costs. The problem here is that one advantage, why is the choice stick-built instead of prefabrication just because of cheaper labor?

## **Research Goal**

The goal of this research is to better understand advantages and disadvantages of introducing prefabrication into Main & Gervais. By including the disadvantages, it will be clearer if the advantages are actually worth the effort of prefabrication. The idea is to find a method to ensure maximum quality in the final project while reducing the schedule in the process. After establishing the implications of this research, it will be important to apply these ideas to Main & Gervais to fully understand the advantages of prefabrication.

## **Research Methods**

The first section of this research outlines advantages and disadvantages of the current method for construction of the curtain wall on Main & Gervais, which is the stick-built method, and compares it to the prefabrication method. The second section observes the current schedule of the curtain wall and provides a new schedule if prefabrication were chosen instead. The third section breaks down the costs of both methods and identifies the one that costs less. Lastly, the final section summarizes the main points of this analysis.

## Construction Method Evaluation

### Current Method

The current method of construction for the curtain wall system for Main & Gervais is stick-built. There are various advantages and disadvantages associated with this method. These are outlined in the table below and further described in the following paragraphs. By acknowledging the problem, it can be understood how we can approach a better solution.

Advantages	Disadvantages
<b>Money:</b> If this method is in a geographical location that is not unionized, the labor has the potential to be cheaper	<b>Time:</b> Construction of the curtain wall system can take longer if the majority of the assembly takes place on-site
<b>Delivery:</b> The materials that are necessary for a curtain wall can be effectively compacted on a truck and delivered to site	<b>Site Condition:</b> With all the materials being delivered to site, it creates the opportunity for clutter to develop
<b>Flexibility:</b> There is more flexibility for the workers when constructing the panels since they are manufactured on site	<b>Quality Control:</b> The quality diminishes when the assembly takes place in an uncontrollable environment
	<b>Hoisting:</b> Curtain wall provides another set of materials that could hog the hoist and limit the time for use from other trades

**Table 3.1: Advantages and Disadvantages to Stick-Built Construction**

As shown in the table above, the disadvantages outweigh the advantages. All the materials are delivered to site but with all the materials on site at once it can congest the site. There are other trades that need space as well, for example, the drywall contractor will need space to lay down all his drywall. Also, having all the materials separate on site requires all them to be assembled together just before installation. The environment is always variable in terms of what other trades will be around and how the weather pans out. This insecure environment could damage the materials.

Because all the construction in a stick-built situation takes place on site, it presents some more problems. On-site assembly requires more workers to be on site assembling the curtain wall. The workers must assemble the metal, stone, glazing, and insulation, and then finish up with caulking. All these steps could be done by the same workers on a non-unionized project. The testing on site is limited to none. Therefore, any leaks could potentially be missed. This could cause moisture problems in the future.

The advantages to stick-built include a better delivery system for the materials and the potential to save money on labor costs. The materials will come in on trucks packed as effectively as possible to maximize how much material is brought in one trip. This will reduce the amount of trucks coming in and out on such a small site plan. There are not many unions in Columbia, South Carolina, which is where Main & Gervais is located. This will result in cheaper labor costs.

## Proposed Method

Now that the current method is analyzed, it is important to take a look at an alternative method. An alternative method for curtain wall construction is prefabrication of the panels. Like any method, there are several advantages and disadvantages associated with the activities involved. Outlined in the table below are these important points and following are paragraphs describing these points even further.

Advantages	Disadvantages
<b>Time:</b> The time it takes to enclose a building is significantly shorter and can allow interior trades to begin	<b>Delivery:</b> The panels large size will require more trucks and the obscure arrangement on the truck will result in “shipping air”
<b>Quality Control:</b> Panels are manufactured in a controlled environment, which increases the quality of the final product	<b>Crane:</b> More crane use and operator engineer employment would be necessary to lift panels into place for installation
<b>Site Condition:</b> There is no clutter from assembling the panels because this is done in a plant where the waste is controlled	<b>Cost:</b> The cost to have the panels manufactured at a plant off-site is set higher because of the higher quality and facility costs (labor, equip., material)
<b>Secure Barrier:</b> The panels are secured tightly to prevent leaks of any kind through the curtain wall, which limits any damage in the future	

**Table 3.2 Advantages and Disadvantages to Prefabrication**

The table above shows some distinct advantages that come with some disadvantages. The time it takes to enclose the building with prefabrication is a considerable advantage to have on a construction project. The panels are assembled off-site so all that is necessary to take place on-site is lifting the panel into place. If the building can be enclosed quicker, the interior trades can begin working on their projects sooner, which can speed up the schedule. Speeding up the schedule can also save money.

Having the panels assembled off-site has some specific advantages. The manufacturing plant ensures a secure environment to assemble the panels. This results in a better quality final product when the panel is complete. After the panel is complete, tests can be conducted to thoroughly check if the panel is secured properly, which will prevent any leaks to occur after installed in the field. Another point to consider, since the panels are assembled before they arrive on-site, there is no clutter on-site due to extra materials and laborers creating unnecessary mess.

With the advantages stated, there are some disadvantages as well. The cost increases to cover the manufacturing expenses including labor, equipment, and material in the facility. While having the panels manufactured off-site ensures a better quality panel, it has to be shipped that way. Because of the inability to compact the panels on a truck bed, there is a possibility of “shipping air.” This will result in utilizing more trucks to ship all the panels to site for installation, which costs more money. When the panels arrive, they must be hoisted into place by a crane. This will require an operating engineer for a longer period of time depending on what he has to lift in a typical day. Main & Gervais is a cast-in-place structure utilizing the crane and bucket method. Extra coordination would be necessary to mix this activity with curtain wall construction.

# Schedule Evaluation

## Current Schedule

This section displays the schedule of the curtain wall construction for Main & Gervais. The schedules below are portions that focus on curtain wall construction. It is currently set at 50 days for two floors at a time. The activities include: material layout, vertical and horizontal mullion setup, preparation of the glass, and then glazing. After the first activity is complete, that same activity can begin for the next set of two floors. The total schedule for the Curtain wall is set for 115 days.

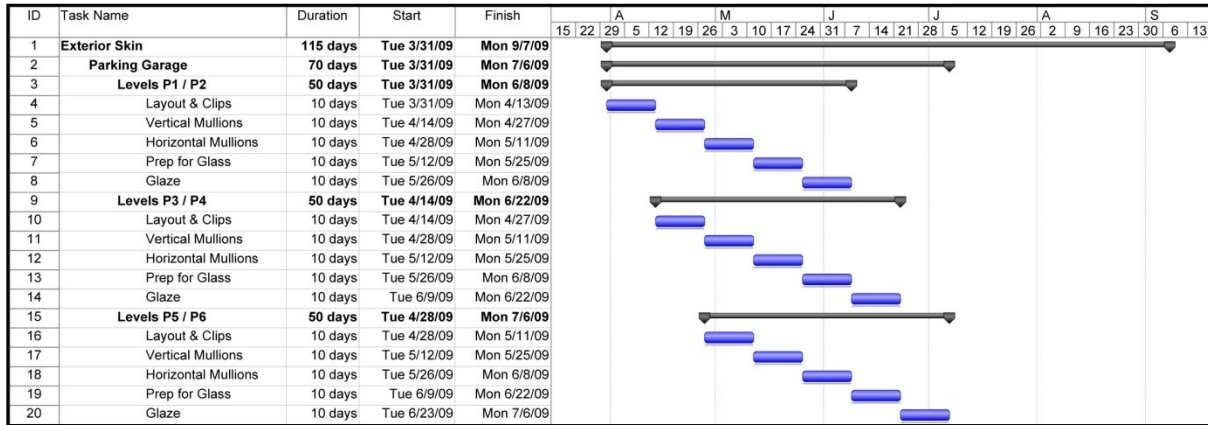


Figure 3.1: Parking Garage Stick-Built Curtain Wall Schedule

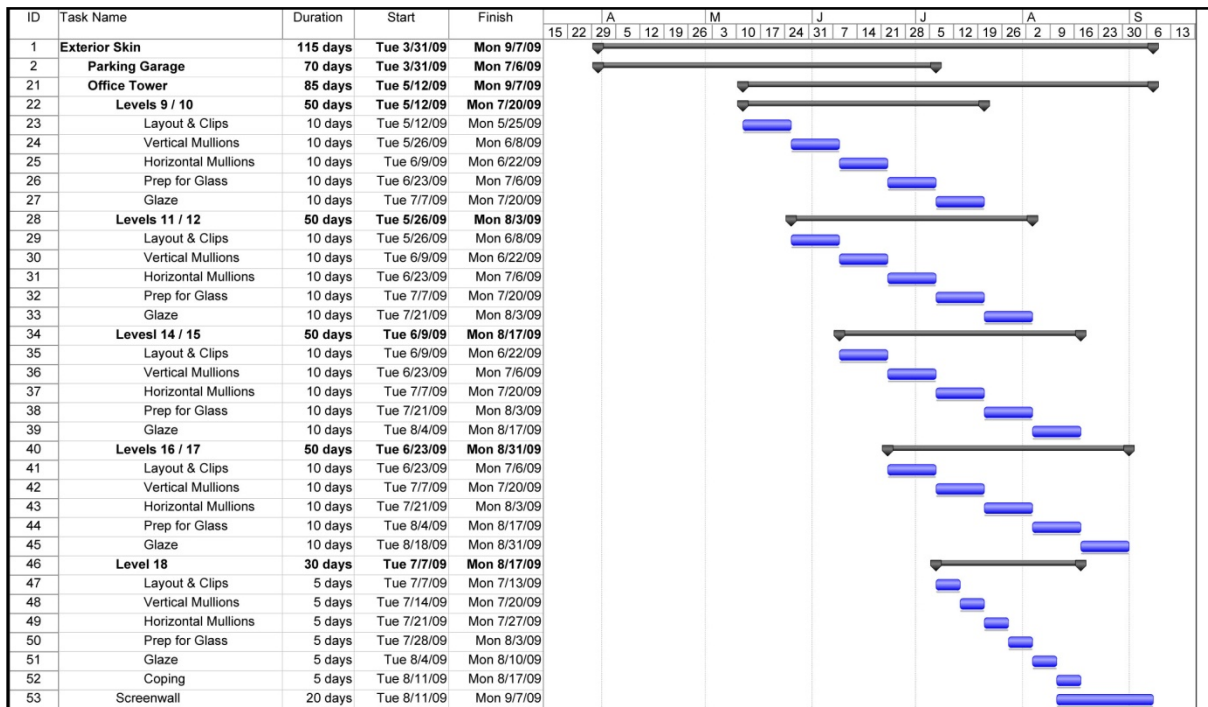
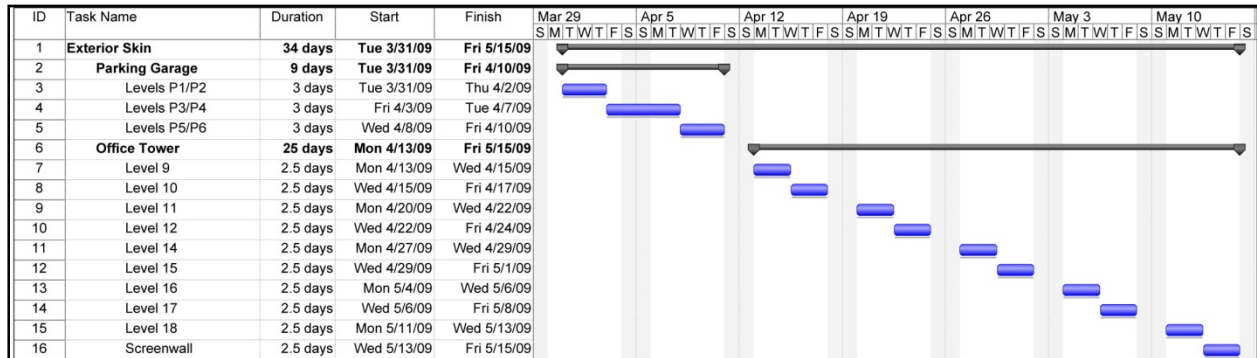


Figure 3.2: Office Level Stick-Built Curtain Wall Schedule

## Proposed Schedule

After understanding the current schedule, it is appropriate to view an alternative schedule provided prefabrication of the curtain wall is selected instead. As shown in **Figure 3.3**, the exterior skin would take a total of 34 days to complete. Each line item is identified by the floor where the curtain wall panel installation is to take place. Installation is the only activity because the panels are manufactured before they arrive on-site. The few assumptions made to implement this schedule are listed below **Figure 3.3**.



**Figure 3.3: Entire Building Prefabrication Curtain Wall Schedule**

## Assumptions

- ~42 panels can be delivered to site each day by truck
- ~50 panels can be installed each day
- A manipulator crane is used so installation can take place all day
- ~64 panels per garage level
- ~94 panels per office floor

Lifting prefabricated panels into place takes a third of the time it takes to utilize the stick-built method. This difference amounts to a huge time savings of 81 days. This will reduce the amount of time laborers will need to be on-site to construct the curtain wall. Also, there will be fewer laborers because the manufacturing of the panels is taking place off-site. This will reduce labor costs for the curtain wall portion of the project. Another advantage to consider, the building is enclosed faster with this method. This allows the interior trades to start their work earlier. This could lead to money savings since the owner would be able to open his building at an earlier date.

## Cost Evaluation

### Current Estimate

This section outlines the costs for the curtain wall construction for the current method, which is stick-built. Non-union and union labor rates are compared and material costs are added in addition to form a total square foot cost.

	Hourly Rate	Workers	Total/Hr	Hours	Total/Day	Days	Total
Non-Union	\$ 28.47	30	\$ 854.24	8	\$ 6,833.96	115	\$ 785,905.00
Union	\$ 70.00	30	\$ 2,100.00	8	\$ 16,800.00	115	\$ 1,932,000.00

**Table 3.3: Stick-Built Labor Costs**

Item	Cost
Materials	\$ 1,761,095.00
Glass/Panel	\$ 1,158,452.00
Glass/Panel Glazing	\$ 330,000.00
Interior Insulation & Trim	\$ 179,900.00
Imbeds & Inserts	\$ 78,000.00
Caulking	\$ 127,244.00
Total	\$ 3,634,691.00
<b>Material \$/SF</b>	<b>\$ 38.67</b>

**Table 3.4: Stick-Built Material Costs**

As seen in **Table 3.3**, the total cost of labor for the parking garage and office level floors is \$785,905.00. Labor activities include: material layout, vertical and horizontal mullion setup, preparation of the glass, and then glazing. The 115 day schedule is obtained from **Figure 3.1** and **Figure 3.2**. The 30 workers are broken into different groups to work on several activities at once. Once one of the several activities is complete, another set of workers will work on the next activity and so on. The hourly rate for each of the non-union workers is around \$28.47. If the labor is unionized, it would cost approximately \$1,146,095.00 more than non-unionized labor for this project. **Table 3.4** outlines the breakdown for how much each of the materials cost and the total material square foot cost.

	Material	Labor	Total	SF	Total \$/SF
Non Union	\$ 3,634,691.00	\$ 785,905.00	\$ 4,420,596.00	94000	\$ 47.03
Union	\$ 3,634,691.00	\$ 1,932,000.00	\$ 5,566,691.00	94000	\$ 59.22

**Table 3.5: Total Square Foot Cost**

After breaking down the costs for labor and material, the total cost per square foot is \$47.03 for non-unionized labor and \$59.22/ft<sup>2</sup> for unionized labor. This is important to understand as it will be compared to the labor and material costs for prefabricated curtain wall construction in the next section.

## Proposed Estimate

This section outlines the costs for the curtain wall construction for the proposed method, which is prefabrication. The amounts are specifically just for two floors and include the material and labor costs for installing the curtain wall.

	Hourly Rate	Workers	Total/Hr	Hours	Total/Day	Days	Total
Non-Union	\$ 28.47	10	\$ 284.70	8	\$ 2,277.60	34	\$ 77,438.40
Union	\$ 70.00	10	\$ 700.00	8	\$ 5,600.00	34	\$ 190,400.00

**Table 3.6: Prefabrication Labor Costs**

The hourly rate listed in **Table 3.6** is based off union wages, which are higher than non-union laborers because of all the fringe benefits included in union wages. This hourly rate is included in the comparison because the assumption is that prefabrication typically takes place where unions are prevalent. Expensive labor rates is one of the reasons why stick-built is chosen over prefabrication. It is also shown that there are less workers and they work for less time than stick-built. This is because the panels are already completed before arriving to site so that all the labors have to do is lift the panels into place and install them. The amount that is not listed here is the labor cost to manufacture the panels. This amount is included in the material costs.

	Cost/SF	SF	Cost
Material	\$ 60.00	94,000	\$ 5,640,000.00

**Table 3.7: Prefabrication Material Costs**

**Table 3.7** shows another reason why prefabrication is not widely chosen in the industry. The material costs are higher than stick-built material costs. The square foot cost in this table is averaged from different subcontractors. There is a higher cost associated with the material because it manufactured off site in a controlled facility. All the costs listed in **Table 3.4** and the cost of manufacturing off site is included in the \$60.00/ft<sup>2</sup>. The cost of manufacturing off site includes: labor costs for workers in facility, equipment used to manufacture panels, the facility itself, etc.

	Material	Labor	Total	SF	Total \$/SF
Non Union	\$ 5,640,000.00	\$ 77,438.00	\$ 5,717,438.40	94,000	\$ 60.82
Union	\$ 5,640,000.00	\$ 190,400.00	\$ 5,830,709.00	94,000	\$ 62.03

**Table 3.8: Total Square Foot Cost**

The material cost raises the overall cost for prefabricated curtain wall panel construction. With non-unionized labor, prefabrication is \$1,296,842.40 more than stick-built construction, which is a 29% increase in cost. With unionized labor, prefabrication is \$263,709.00 more than stick-built construction, which is a 5% increase in cost. In the case of Main & Gervais, it is obvious why stick-built is the chosen method for curtain wall construction because it is in a non-unionized location. If the project were located where unions were prevalent, prefabrication might be a smarter choice because a 5% increase would be worth it for a better final product and a faster schedule.

## Conclusion

Prefabrication and stick-built curtain wall construction were evaluated under three different categories. These categories include advantages and disadvantages, schedule factors, and cost considerations. The following conclusions were obtained after conducting research.

### Advantages and Disadvantages

The major advantages for stick-built construction are cost savings and delivery flexibility. The labor and material costs are less than prefabrication. Also, delivering curtain wall materials to site unconstructed allows for a larger quantity of material to fit on a truck bed for each trip. The major drawbacks of this method are a slower schedule, lower quality final product, and a messier site.

Prefabrication lends itself to several different advantages but has one major drawback. The advantages include a better quality final product, faster building enclosure, and a cleaner site. The cost for these advantages is primarily an expensive budget. It costs more to prefabricate the panels at a separate manufacturing facility. The owner is less likely to pick this option since it will cost more money.

### Schedule Evaluation

After observing the schedules between the two methods, it was clear to see that the prefabrication method has a faster schedule. The stick-built method takes three times longer than installing prefabricated panels. This is because with the stick-built method, all the construction of the panels takes place on-site. With prefabrication, all of the manufacturing takes place at an off-site facility and all that needs to be done on-site is lifting the panels into the proper location. To enclose the building faster, prefabrication is the method of choice.

### Cost Evaluation

Comparing the two methods through estimating means establishes an advantage for the stick-built method. Prefabrication costs 29% more than the stick-built method with this particular project if labor is not unionized and 5% more if labor is unionized. Therefore, the method of choice is stick-built construction because it is cheaper where there are non-union wages.

### Final Comments

After summarizing the different evaluations performed in this report, a link between the evaluations is found. It is important to note that the schedule is shortened by 81 days with the prefabrication method. This could imply a quicker building turnover for the owner. Assuming the owner can begin leasing out the available space over more than two months earlier would indicate the owner could bring in rent money earlier.

Office Area	\$/ft <sup>2</sup> /year	Year	81 Days	Non-U Difference	Union Difference
200,000	\$ 21.00	\$ 4,200,000.00	\$ 945,000.00	\$ (351,842.40)	\$ 681,291.00

**Table 3.9: Extra Rent Income**



**Table 3.9** indicates an extra \$945,000.00 in income from an earlier turnover. This amount can contribute to the extra amount it costs for prefabrication. If non-union wages are utilized, there is still a loss of \$351,842.40. Though, prefabricated curtain wall panels may be more enticing because now it is only 8% more than stick-built construction with this factor included instead of 29%. The owner of Main & Gervais may find a better quality product in prefabricated panels worth the extra 8%.

On a side note, in an area where unions are prevalent, it would be a savings of \$681,291.00. So it is wiser to choose prefabrication in this situation, which seems to be the case already in locations where there are unions.

In conclusion, the choice is likely to remain stick-built construction over prefabrication for a majority of the time. Instances where prefabrication is an option are locations where unions are prevalent and sites are rather congested. For example, New York City would choose prefabrication construction because constructing stick-built panels on-site is very inefficient due to the lack of space and limited daytime construction. Also, there are more unions in this location. Prefabrication would allow a quick efficient installation while utilizing less labor. If the owner is looking to close up the building in a third of the time it would take for stick-built construction, it may be a smarter choice to go with prefabrication. For now, stick-built construction will remain a cheaper alternative until material costs for prefabrication decline. This could eventually happen if prefabrication is chosen more often, which would bring the prices down because of more competition.