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Tech Report 3
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CityCenterDC | Parcel 1

Washington, D.C.

Executive Summary

The focus of Technical Report 3 is to investigate areas of the project suitable for further research and thus form a basis for the final thesis proposal. Through the exploration into LEED, schedule risks and acceleration scenarios, value engineering, and critical industry issues, several ideas for technical analyses were derived.

One of the unique aspects of the LEED Gold Certification process for CityCenterDC was the use of the Neighborhood Development (ND) rating system. This system, established to create a standard for rewarding neighborhood establishment projects, was deemed appropriate for this project. While the ND rating system does not focus as much on green building practices on a per building basis, it takes into account all the elements that make the development beneficial to the community. An additional exploration into the sustainable aspects of Office Building 1 determined that a similar level of certification would have been achieved under the NC rating system.

After analyzing the critical path of the project, several risk and schedule acceleration scenarios were identified. The MEP rough-in process and post-tensioned slabs posed the largest potential for delays in the schedule, while the prefabrication and coordination of repetitive work created the opportunity for schedule acceleration. These considerations were a key part of investigations into additional research topics.

The value engineering process for CityCenterDC was a very structured and successful series of events. Multiple meetings between the owner and construction/design teams yielded a list of 200-300 items. Although cost savings were an important consideration, the goal of the owner was to improve the quality of the project. The inclusion of an on-site concrete batch plant added upfront costs, while value engineering for feeders, fire protection, elevators, finishes, and conduit produced savings.

Interaction and discussion with industry practitioners at the 21st annual PACE Roundtable event served as an additional tool in the search for technical analyses ideas. Breakout sessions about efficient integrated design and modularization generated open discussions between students and practitioners.

Taking these analyses along with the previous technical reports into account, several research topics were generated. The notions these ideas revolve around are, but not limited to, schedule and cost reductions, appropriateness to function of spaces, and improvements to constructability.

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LEED Evaluation

The CityCenterDC development is pursuing a LEED Gold certification under the LEED 2009 for Neighborhood Development (ND) rating system. Due to the size and combination of residential, non-residential, and public spaces, this project was deemed appropriate for the Neighborhood Development Pilot Program. Since these types of development projects have significantly longer construction durations, CityCenterDC was assigned a Stage 2 conditional approval, meaning it was pre-certified as LEED Gold. Out of the 110 possible points, it achieved 67, placing it comfortably in the Gold certification range.

Instead of utilizing the standard LEED for New Construction certification system, the project team chose to pursue certification from the most recently released LEED for Neighborhood Development. The USGBC, in conjunction with the Congress for the New Urbanism and the Natural Resources Defense Council, created this system in order to establish a standard for rewarding neighborhood establishment projects. While other LEED rating systems focus on green building practices, the ND system places emphasis on site selection, design, and construction elements. The goal is to bring buildings and infrastructure together, and integrate them with the neighborhood, landscape, and regional context. All the elements of the development should be beneficial to the community and individuals, as well as the surrounding environment.

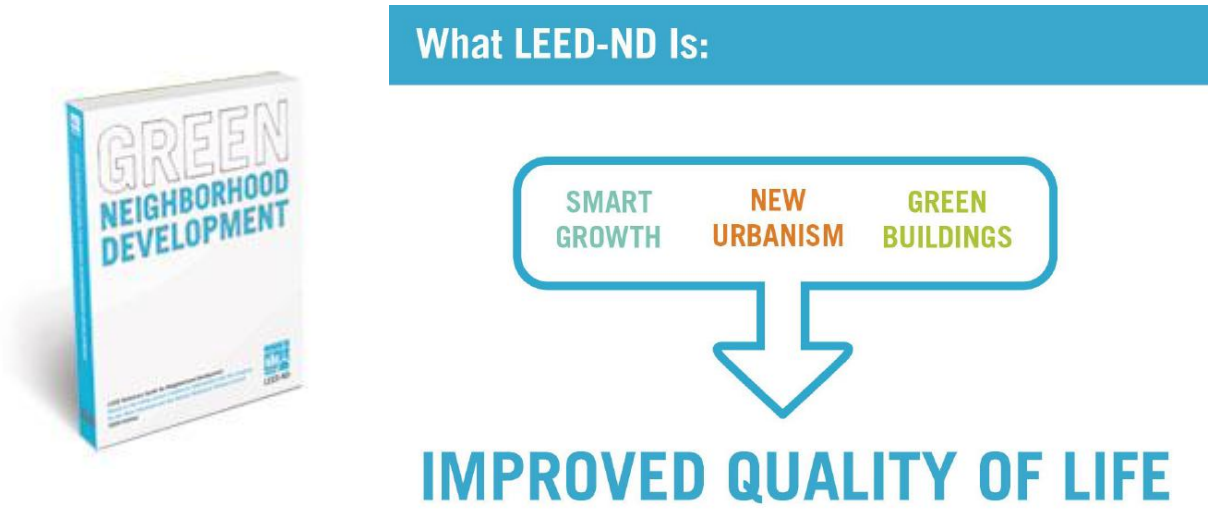

Figure 1: LEED Neighborhood Development | Images courtesy of USGBC

While other LEED rating systems typically have five categories, ND has only three. Please refer to the table below for a comparison of categories between two LEED rating systems. Note that the last two categories are considered bonus categories. Also, the LEED evaluation performed in this technical report focuses on the entire CityCenterDC development. It does not concentrate on any specific building; rather it considers the "neighborhood." Refer to Figure 2 for points earned and not earned in each category of the ND rating system.

Table 1: LEED Points Distribution

LEED for New Construction & Major Renovations	Points Possible	LEED for Neighborhood Development	Points Possible
Sustainable Sites	26	Smart Location and Linkage	27
Water Efficiency	10	Neighborhood Pattern and Design	44
Energy and Atmosphere	35	Green Infrastructure and Buildings	29
Materials and Resources	14	*Innovation and Design Process*	6
Indoor Environmental Quality	15	*Regional Priority Credit*	4
Innovation and Design Process	*6*		
Regional Priority Credit	*4*		

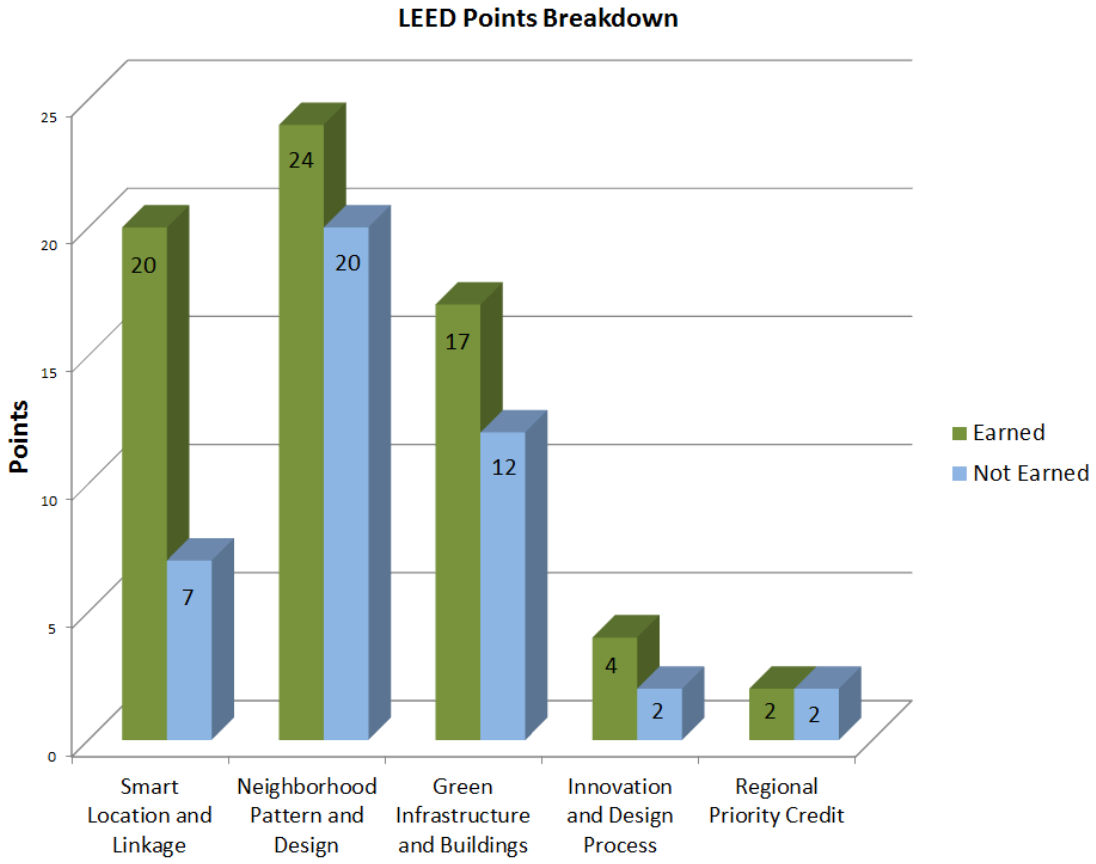

Figure 2: Points Earned vs. Not-earned

Prerequisites

In order for the ND rating system to be chosen, several prerequisites in each category had to be fulfilled. The following is a quick overview of the prerequisites for each category.

Smart Location & Linkage

- **Smart Location** – encourage development within and near existing communities and public transit infrastructure.
- **Imperiled Species and Ecological Communities** – conserve imperiled species and ecological communities.
- **Wetland and Water Body Conservation** – preserve water quality, natural hydrology, habitat, and biodiversity through conservation of wetlands and water bodies.
- **Agricultural Land Conservation** – preserve irreplaceable agricultural resources by protecting prime and unique soils.
- **Floodplain Avoidance** – protect life and property, promote open space and habitat conservation, and enhance water quality and natural hydrological systems.

Neighborhood Pattern and Design

- **Walkable Streets –** promote transportation efficiency, including reduced vehicle miles traveled and to promote walking by providing safe, appealing, and comfortable street environments.
- **Compact Development** – conserve land, promote livability, walkability, and transportation efficiency, support transit investments, and encourage physical activity.
- **Connected and Open Community** – promote projects that have high levels of internal connectivity and are well connected to the community at large.

Green Infrastructure and Buildings

- **Certified Green Building** – encourage design, construction, and retrofit of building that utilize green building practices.
- **Minimum Building Energy Efficiency** – encourage design and construction of energy-efficient buildings that reduce air, water, and land pollution.
- **Minimum Building Water Efficiency** – reduce effects on natural water resources and reduce burdens on community water supply and wastewater systems.
- **Construction Activity Pollution Prevention** – reduce pollution from construction activities by controlling soil erosion, waterway sedimentation, and airborne dust generation.

**Description of prerequisites provided by USGBC.*

Summary and Analysis of Point Categories

Smart Location and Linkage

The first category focuses on the location of the project and the way it links to its surroundings. One of the first criteria that CityCenterDC met was that it is located on a previously developed site, the former city convention center. The area was also deemed a high priority redevelopment area due to its prime location. This location allowed for reduced automobile dependence due to its proximity to the metro system and bus stops, accounting for several more points. In addition, since it is a mixed-use development, the housing and job proximity criteria under the category were met. The combination of these features was a very appropriate fit for the category, as 20 out of the 27 possible points were met.

Neighborhood Pattern and Design

The largest point category in the ND rating system involves the design of the project in respect to the neighborhood pattern. Once again, the combination of residential and non-residential densities allowed the project to gain many points in this category. The entire development is surrounded by tree-lined and shaded walkable streets. This allowed for a mixed-use neighborhood to exist within the perimeters of the project. In between all of the buildings is a courtyard space designed to bring the residents of the buildings together. Parking is located underneath the development, eliminating an exposed parking footprint. By introducing a new street in between the buildings, the street network was also expanded. As a result, access to the civic and public spaces of the development and beyond was expanded. Another crucial aspect to the LEED certification began in the planning stages of the development. Several community outreach meetings and sessions were held in order to involve the surrounding community and take into account their perspectives and concerns. This is a vital aspect of creating the idea of a united neighborhood. With all of these features of the project, 24 out of 44 possible points were achieved.

Green Infrastructure and Buildings

In order to fulfill the credits required for the third category, the buildings themselves had to meet green building practice standards. A stormwater management system was developed in the surrounding landscape and roofs to collect rain water. This water is then processed and used throughout buildings for various graywater needs. In addition, water efficient fixtures were used throughout to meet the water efficiency criteria. The green roofs also helped control the heat island effect, a large concern in an urban environment. It was through the use of green roofs, landscape features, materials, and systems that the CityCenterDC development met a large amount of criteria for this category. Out of the 29 possible points, 17 were met.

Critical Evaluation

The decision to use the LEED for Neighborhood Development rating system was very appropriate for the CityCenterDC project. The ND rating system did not exist during the initial design stages of the project. As such, the buildings were designed to meet many of the traditional LEED credits for new construction. The neighborhood principle was however considered from the onset. As the new ND rating system developed during the design stages of CityCenterDC, the design was altered to incorporate its criteria. This meant that the original new construction green principles remained, and additional ones were added.

The ND rating system matches the goals of the developer and the potential clients. It provides a more accurate analysis of how green the project is by considering all of its components. The one aspect that it does not focus on much however is the construction methods. Little emphasis is put on the construction stages of the development, which in other rating systems would be much more substantial. Although they did not receive many points for their methods, many green construction techniques, including extensive recycling, were utilized. This was owed to the owner requirements and the mindset that it was the responsible approach. The developer's goal to make a positive impact on the community is demonstrated appropriately through the LEED certification it seeks.

Please refer to Appendix A for a project scorecard of the specific points attained for the LEED Gold certification.

Other LEED Considerations

An analysis of the green features of Office Building 1 was performed using the LEED for New Construction (NC) rating system. This system focuses more on the green building practices applied to a building. Some of the design features not mentioned in the ND rating system include the heat island effect, green power, materials, controllability of systems, and monitoring of systems. While these systems were not included in the ND rating system, many of them were applied to Office Building 1. This is due to the owner's request to build a responsible and green building. Commissioning, waste management, and an IAQ management plan are among the construction features not mentioned in the ND rating system, but once again, applied by the project team due to the goals of the owner. In conclusion, a similar Gold Certification would have been achieved for Office Building 1 under the NC system as was for the entire development under the ND system.

Schedule Acceleration Scenarios

Office Building 1 of the CityCenterDC development was the first of six buildings to break ground and subsequently finish, making it a reference for the entire job. Due to the customization factor associated with such a large tenant space, the substantial completion date was extremely important to the project team. The following section outlines the critical path for Office Building 1, along with the risks and potential acceleration scenarios.

Critical path

In addition to the critical path of the project, the substantial completion of the building is one of the owner's top priorities. Once the building reaches substantial completion, the tenant fit out process can begin. A 250,000 sq. ft. building will require considerable time to be furnished with all the finishes and details the tenant requests. As a result, the quicker the building reaches substantial completion, the quicker the owner will start to receive revenue from the tenant.

The critical path of the actual construction revolves around the enclosure and rough in of critical spaces. As seen in the diagram below, which outlines the critical path, these are the ground floor and penthouse. The penthouse is a priority because it contains a mechanical room. Having the mechanical room ready to tie in to the rest of the building is consequently a top priority. The ground floor is in the critical path because it is intended retail space, not linked to the rest of the floors. Once again, the sooner the retail spaces are finished, the sooner the owner can sign a lease with a tenant and begin to bring in revenue. The combination of the core and shell structure along with the tenant fit out stages call for system rough ins to be the most important features during construction.

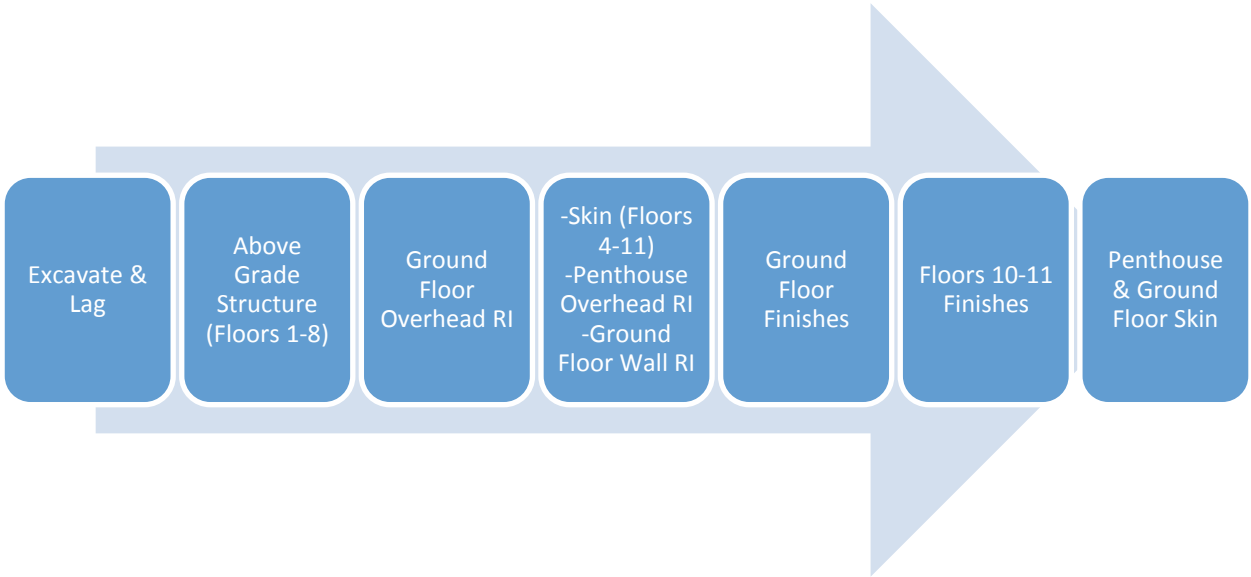

Figure 3: Critical Path

Risks

As noted in the critical path overview, the MEP system rough-in is vital to the timely completion of the building. As such, the largest risk stems from improper or postponed installation. Lead times and on-time deliveries can cause such delays. If the project team does not complete their equipment submittals on time, they may not receive their equipment as planned. Lead times on major mechanical and electrical equipment can be approximated to 8 weeks. A two week delay in the submittals means a two week delay in receiving the equipment. Without the equipment in place, the rough-ins and tie-ins cannot be completed. This also means that commissioning cannot start. All of this adds up to lost labor time, as the laborers will still be there but they will not have enough to do. The costs associated with this labor run on an hourly basis, and can add up very quickly. Furthermore, the delay in schedule means the owner will not be able to lease the space as quickly as desired, losing potential revenue.

The post-tensioned slabs and embeds pose the other major schedule risk. Once a slab is post-tensioned, it is extremely difficult to make any changes to it. Cutting or boring it is difficult because of the array of cables. Therefore, if an embed is improperly placed and requires relocation, the entire slab's structural integrity may be threatened. In that case, the slab may need to be completely redone. This would call for demolition of the existing slab, lost material, time to pour and tension a new slab, and the entire schedule delays associated with the dependent activities to the slab. Not only would the schedule be greatly affected, but the costs accrued would be very significant. To prevent such an occurrence, the construction team used Trimble equipment, as seen in Figure 4, to precisely locate the resting place of the embeds. After a final quality check, the slabs were poured.

Figure 4: Slab Coordination

Potential Acceleration

The repetitive design of many aspects of the building creates the opportunity for several schedule acceleration techniques. The core of each floor, excluding the ground and penthouse levels, is identical in design. As such, it creates an ideal opportunity for the implementation of a SIPS schedule. With several crews assigned to specific tasks, such a schedule could increase the efficiency and consequently speed up the schedule. Prefabricating some of the MEP system components would also assist the crews and produce additional savings. This plan would have to be carefully planned and executed in order to produce schedule and cost savings.

The decision to prefabricate the bridges in between the office buildings benefited the project in several ways. First, the danger associated with constructing a structure several stories in the air was eliminated. Due to this safety concern, while the bridges were being constructed, all work in that perimeter would have also needed to come to a halt, creating schedule delays across the board. Choosing to prefabricate the bridges eliminated the concerns of other trades and activities. In addition, the workers productivity in the warehouse is significantly higher than it would have been on site. All of these factors translate not only into schedule acceleration, but cost savings in terms of labor hours and rates.

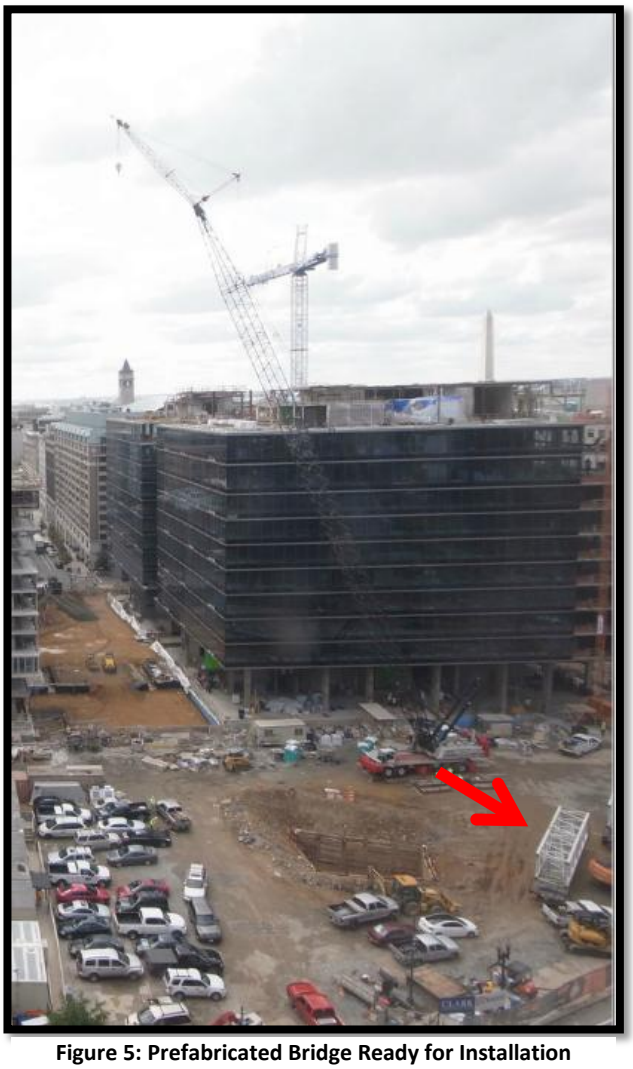

Figure 5: Prefabricated Bridge Ready for Installation

Value Engineering

In an effort to add value to the project, the designer, contractors, and owner worked together to create a list of value engineering ideas. While costs were an important consideration, the goal was to improve the quality of the project. The initial list consisted of approximately 200-300 items. While not all were applied, the ones that passed went through a 60 day review from the designers, contractors, and owner. The following are some keys areas of value engineering implemented on the project.

Feeders

The developer of CityCenterDC provides a service and maintenance program for the main switchgear and equipment every six months. The purpose behind the program is to extend the life of the systems in the building and ensure proper function. Part of the servicing includes torqueing the feeder connections. As such, the idea to switch some of the copper feeders to aluminum was proposed. Aluminum is cheaper than copper, but needs to be serviced more often. Since the developer already has a program set in place to do such servicing, this was a logical proposition. By specifying a number of the large feeders to aluminum, the team was able to cut approximately $100,000 in costs. This did not affect any other aspects of the construction logistics, as it was simply a material switch-out.

Figure 6: Aluminum vs. Copper Feeders | Image courtesy of Google Images

Exhaust Fire Protection

During the analysis of the fire protection for various systems, the team discovered a redundant feature of the kitchen exhaust. By code, the exhaust needs to be fire protected until it reaches its final destination. In the design, not only was the exhaust run through a fire protected shaft, but fire coating was also applied to it. After verification from both the engineers and the code, it was deemed that the fire protection wrapping of the exhaust was not necessary. Eliminating this feature yielded a savings of approximately $130,000. The careful inspection of the systems by the entire team led to the discovery of this redundant feature, and resulted in significant cost savings.

Elevators

The typical elevator frames and/or doors throughout the building are made of stainless steel. After considering the locations of all the elevators, several were designated as "back-of-house," meaning they were not exposed to the general population of the building. As such, using stainless steel, a considerably expensive material, on these elevators was unnecessary. The stainless steel was replaced with standard baked enamel, producing a savings of $178,000.

Ceiling spaces

In the original specifications of the ceiling spaces, a plaster veneer finish was utilized. With the presence of a dropped ceiling though, these finishes would not be exposed to the tenants. As such, the team decided to replace the veneer with a skim coat. The skim coat performed the same function as the plaster veneer, but produced a savings of $580,000. This is a very significant value engineering solution to a feature that would not affect the appearance or function of the space.

Conduit

The electrical engineer for the project also played a role in proposing value engineering ideas. Instead of using EMT conduit for the office building, MC cable was applied. This substitution did not affect the performance of the system, but reduced the material cost by $250,000. The inclusion of the engineers in the value engineering process allowed this change to happen. In addition to the cost savings, MC cable is also much less labor intensive. EMT requires pipe bending and many more fittings. By using MC cable, the schedule associated with installing the conduit was also accelerated.

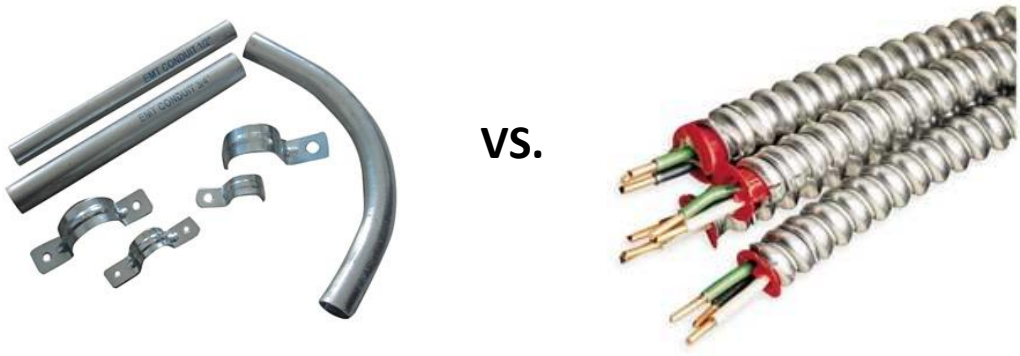

Figure 7: EMT vs. MC Cable | Image courtesy of Google Images

Summary

Throughout the value engineering process the owner emphasized the importance of improving the quality of the project. While cost savings were desirable, if they threatened the quality of the building, they were not implemented. The extensive initial list detailed many solutions, but only those deemed appropriate were applied. With the high-end clients desired, many of the visible finishes were important to the owner. Propositions that involved cheaper materials for these finishes were not always implemented. Another value engineering implementation was the use of a concrete batch plant. Although the up-front costs to rent the plant were high, they reduced the complications associated with deliveries, quality, and schedule impacts. The large amount of concrete needed for the job would have required constant deliveries. Deliveries in the middle of city would not only threaten the schedule through delays, but also could affect the quality and workability of the concrete. Through the communication and planning of the entire project team, the value engineering process proved a success.

Critical Industry Issues

The annual PACE (The Partnership for Achieving Construction Excellence) Roundtable Meeting was held on November 6, 2012 at the Penn Stater Conference Center. In attendance were top industry professionals, Penn State faculty, and 5th year Architectural Engineering students. The topic of this year's roundtable was "Improving Efficiency through Innovation." The meeting began with an overview of the research and work Penn State is currently committed to. Shortly thereafter, a student panel discussion opened. Four students were asked to speak about their experience and involvement with BIM studio and BIM thesis. They were asked to identify positives and negatives of the programs, and suggest ways to improve them to future years. The panel discussion closed with several questions from industry practitioners directed towards the students.

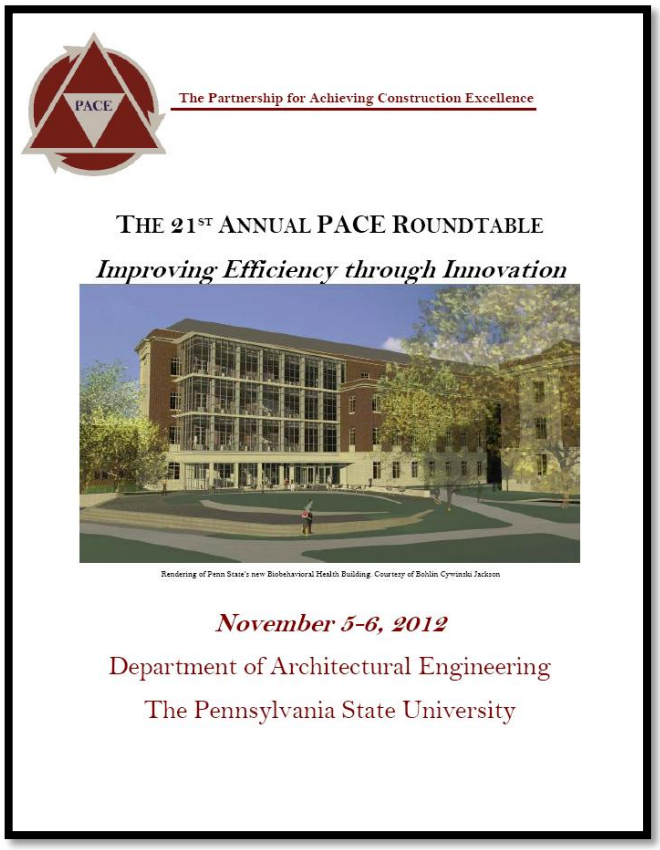

Figure 8: 21st Annual PACE Rountable | Image courtesy of PSU

Following the student panel were the three main breakout sessions: Supply Chain, Efficient Delivery of Services, and Operations and Maintenance. Each session focused on a particular topic in that category. Led by Penn State professors, the discussions would encourage industry practitioners and students to interact and discuss the respective topics. It also served as a tool for students to gather ideas and advice for their senior thesis projects. At the conclusion of the breakout sessions, industry practitioners were assigned several students for a feedback meeting. Each group then proceeded to discuss a topic from the breakout sessions they deemed most appropriate for their projects. The ensuing section focuses on two breakout sessions, *Efficient Use of Integrated Design* and *Modularization*, respectively

Breakout Session #1 – Efficient Use of Integrated Design

In the first breakout session, the topic of discussion was the *Efficient Use of Integrated Design*. Led by Dr. Riley, the discussion began with a brainstorming session. Both students and industry practitioners actively developed a list of key words and topics associated with an integrated approach. Topics ranged from design to construction, and legal aspects to human nature. Individuals in the room included graduate students, undergraduate students, and industry professionals (designer and construction).

Following the brainstorming session, the group proceeded to define what an integrated design approach meant. While answers varied from person to person, the group collectively agreed that an integrated approach must embrace the collaboration of the entire project team. Each individual then commented on a particular aspect of an integrated approach that was relevant to them. Because subcontractors, general contractors, and design firms were represented, answers varied. It was interesting to observe the responses from the remaining individuals in the room once someone voiced their concerns. The discussion then turned into taking these issues and applying realistic solutions to them. It was identified that human nature plays a very large role in the success of these approaches. The legal aspects of a contract were also thoroughly discussed. Many industry practitioners noted that they were restricted by contacts very frequently. A contract can dictate the contractor or designers ability to participate in an integrated approach. Other times, the contract would work against the integrated approach. Surprisingly, many of the concepts discussed were agreed upon by most of the practitioners.

One of the interesting discussion topics was how the role of individuals on projects changes with a more integrated system. The group first analyzed the history of the roles of project team members. The “master builder” concept was mentioned, and how the industry has deviated from this role. As delivery systems have evolved, so have the responsibilities and expectations of the separate members. As such, the importance of communication was discussed. In order to keep every member of the team informed, the leaders must enact a system to ensure everyone is aware of their duties. The decisions on who is responsible for what should be made collectively to avoid confusion. Despite not using an integrated delivery system on CityCenterDC, the project team could analyze the effectiveness of their communication system in respect to each contractor’s responsibilities. The sheer size of the project leaves many areas for disputes concerning which contractor is responsible for that particular section of the work. As a result, identification and communication of roles is vital even to project teams not committed to IPD.

Being that IPD is a fairly new concept, the industry must establish a way to judge whether or not an integrated approach is appropriate for specific projects. As emphasized by all of the industry practitioners, every job is different. As such, it is hard to define rules and guidelines of what an integrated delivery system must embody. Rather, it is more beneficial to define the goals and ideas behind an integrated approach. This way the team can sit down and create rules and guidelines specific to their project. Ideas such as colocation should be discussed by the team, and based on project specifics, identified as appropriate or not. CityCenterDC planning started nearly a decade ago, when IPD was not a very popular topic. With more research, statistics, and application today, it would be interesting to perform a study on how a more integrated delivery system would affect the project. The first step would be to determine if such a system would be appropriate for the project, and if so, the steps the team would need to make to ensure its successful implementation.

Breakout Session #2 – Modularization

The second breakout session, led by Dr. Messner, focused on *Modularization.* Similar to the first session, the group first brainstormed ideas and words describing modularization. The discussion then moved towards the industry practitioners describing their personal roles in modularization. Employees of both Truland and Southland led the discussion, as it was deemed that a large majority of prefabrication and modularization is performed by the MEP trades. They each described the processes they took to prefabricate their systems. Both companies agreed that prefabricating certain components was vital to their success. They also stressed that a project team and owner must be committed to prefabrication from the beginning of the project. Implementing it in the middle would not yield the intended results, and could actually hurt the project.

One of the interesting research topics discussed was to what extent one can modularize components of a building. Different examples were given by individuals in the group, ranging from head-boards to entire rooms. A collective conclusion was that it was a very project specific topic. The owner requirements for safety, quality, and schedule would in turn determine how much modularization was necessary. Also, the qualifications and capabilities of each contractor would also at times limit the extent to which a system could be modularized. Companies in cities such as Washington, D.C. usually have the capabilities to prefab many aspects of a job. The situation is not the same in smaller towns or communities throughout the country though. As a result, it is important to identify the types of factors that influence the ability and extent to which a job can be prefabricated. Relating this topic to CityCenterDC opens a variety of research opportunities. While prefabrication did exist on the job, it would be an interesting study to find the extent to which it could have been applied and compare it the current plan. Some of the industry contacts from the breakout session were actually on the CityCenterDC job, making it a very interesting opportunity to explore for my thesis project.

The other key issue regarding modularization was cost vs. benefit. Did the benefits always outweigh the costs? Or were the costs so high at times that using modularization was not worth it? As the discussion progressed, it became clear that the two major factors associated with the cost vs. benefit analysis of modularization were price and schedule. At times, the schedule could be improved by using modularization, but the costs associated with it were more than if it was not used. Other times, there would be both schedule and cost savings. Regardless, the successful use of modularization always meant that it needed to be applied at the onset of the project. Relating this concept to CityCenterDC, it is a unique opportunity to research the prefabrication techniques utilized and their cost vs. benefits. The most relevant of which are the modularized bridges discussed in Technical Report 2. The involvement of multiple trades and size of the modularized units is a very interesting topic to research. The

two main reasons behind choosing to prefabricate the bridges were safety and schedule. An interesting area of study would be to find out the finances associated with the technique. Towards the conclusion of the breakout session, students asked industry practitioners questions concerning their specific thesis reports.

Summary

The PACE Roundtable was a very informative and beneficial event. The breakout sessions were a great way for students to both hear viewpoints of practitioners as well as interact with them. The open discussion idea was set up in a way that students could participate in the discussion. Surprisingly, industry practitioners agreed, more often than not, on issues that are usually a source of debate on a job site. That is, the discrepancies and dilemmas that occur between trades were not treated as such in this open discussion. After analyzing this observation, it seems that in the big picture, everyone is basically on the same page. The flaws and deviations occur because of some external factor. This factor may be personal or an unforeseen condition. Regardless, the fact that people can identify the responsible course of action proves that we are one step closer to finding solutions to problems the industry faces. In conclusion, the discussions and topics raised during the PACE Roundtable were very relevant and informative, and turned out to be mutually beneficial to all participants.

Problem Identification and Technical Analysis

The compilation of material and analyses performed in the three technical reports serves as a precursor to the identification of problematic areas. Despite the success of the project thus far, there are several areas with the potential for improvement. The following sections define problematic areas and identify opportunities for technical analyses.

Schedule Acceleration Through the Use of SIPS

As mentioned throughout the technical reports, floors 3-11 of Office Building 1 are typical. The core of each floor contains, among others, an electrical room, mechanical room, restrooms, and elevator shafts. Consequently, the implementation of SIPS (Short Interval Production Schedule) provides potential for a schedule acceleration scenario, and as a result, cost savings. The current schedule for each floor follows a technique similar to a SIPS schedule, but crews are not clearly identified, and deadlines/durations are not enforced. As such, delays in the field occurred more often.

A technical report exploring the reorganization of the crews and specific assignments would determine whether wasted time could be eliminated and produce a more value adding technique. This would in turn translate to cost savings in both the labor and schedule categories. As mentioned earlier, the quicker the owner can sign a lease and begin the tenant fit out process, the quicker he will begin to bring in revenue. The implementation of SIPS would directly relate to the owner's goal. In addition, Office Building 2 could implement this schedule, as the building design is identical to Office Building 1.

The correlation and affects to the remaining schedule will also be analyzed to ensure that other areas are not negatively affected. After a SIPS schedule is created, it will be implemented into the existing construction schedule. The results of the analysis will determine whether or not this technique is appropriate for Office Building 1.

Electrical Branch System Redesign and Construction Breadth

The intent of a core and shell office building is to provide tenants with an easily customizable, open floor space. Because every tenant's needs will be different, the owner must anticipate different and changing floor layouts throughout the life span of the building. As a result, if the design revolves around this notion, the owner will reduce future costs associated with fit-outs and changing floor layouts. One such system that poses potential for a more efficient redesign is the electrical branch distribution.

The current standard overhead electrical distribution system ties into the electrical closets on each floor. Conduit will be run down from the ceiling to the desired receptacle locations. The typical floor layout however does not contain any walls, and very few columns. This means that it will be difficult to reach all desired receptacle locations. If the floor layout consists of a "cubicle farm,' such drop downs from the ceiling will not only be visually distracting, but also require much more work in the event of a new layout.

Instead of using a standard overhead electrical distribution system, a technical analysis exploring a SnakeBus system will be performed. SnakeBus consists of a 3" raised floor system, housing easily configurable buss bar. Tie in points can be made at any point of the buss bar through built in receptacle boxes. The layout configuration is easily customizable and reconfigurable. The technical analysis will concentrate on designing a system that meets the load requirements. It will also make sure all codes are met.

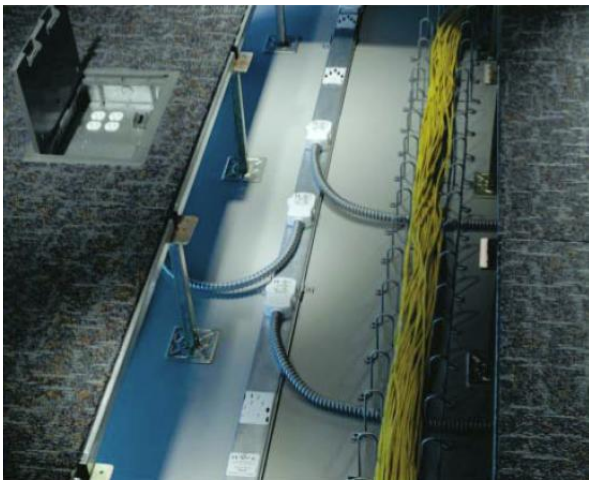

Figure 9: SnakeBus | Image courtesy of SnakeTray

In addition, a cost and schedule breadth analysis will be performed comparing the SnakeBus system to the original system. The constructability of the system will also be analyzed to ensure it does not interfere with other systems or cause additional field problems. The owner's goals will be analyzed to determine whether or not such a system is appropriate for this project.

Raised Floor Construction Impacts and Mechanical Breadth

The current mechanical and electrical systems are not designed optimally for the susceptible floor layouts. With a 99 year lease on the property, the owner will most certainly experience either different tenants or layout reconfigurations. As such, if MEP systems are designed around this notion, as previously mentioned, the owner will reduce complications and costs associated with rearrangement.

A technical analysis comparing the cost, schedule, and constructability aspects of a raised floor versus the current design will provide input to whether such a system is appropriate for this project. The research required will consist of tracking labor rates and costs associated with installing such a system. The schedule aspect will also be thoroughly analyzed due to the previously mentioned early completion goals the owner has. In addition, the developer/owner mentioned that they have extensive experience with raised floor systems in office buildings, so it will not be a completely new feature to them.

A raised floor system will also require a redesign of the mechanical system. The current system utilizes VAVs which must be adjusted with every reconfiguration of the floor layout. A breadth analysis will be performed to analyze an under-floor mechanical system and its efficiency, cost, and practicality for the space. This can in turn be tied into the electrical SnakeBus depth, as it will also be housed in the raised floor system.

Core Electrical and Mechanical Room Mock Up

As previously stated, the core of each floor is typical. As such, the electrical and mechanical rooms are very similar, if not identical, on a floor by floor basis. In addition, the two office buildings of the development are identical, meaning the core of both buildings are very similar. The complexity of such MEP closets means that constructability issues are likely to arise. In order to decrease the possibility of such problems, a technical analysis will explore the effects a mockup has for these core spaces. The research behind creating such a mockup will include looking into constructing a mockup, either onsite or in a warehouse environment, and the way the construction team can implement it. In addition, cost and schedule savings will be explored for using this technique. This analysis can also be tied into the SIPS technical analysis. That is, in addition to the potential benefits of the mockup, a SIPS technique can be applied to the MEP closets to further increase the productivity.

Appendix A

LEED ND Scorecard

LEED 2009 for Neighborhood Development
Project Scorecard

Project Name: CityCenterDC
Date: 11/7/2012

Yes	?	No			
20	4	3	**Smart Location and Linkage**	**27** Points Possible	
Y			Prereq 1	**Smart Location**	Required
Y			Prereq 2	**Imperiled Species and Ecological Communities**	Required
Y			Prereq 3	**Wetland and Water Body Conservation**	Required
Y			Prereq 4	**Agricultural Land Conservation**	Required
Y			Prereq 5	**Floodplain Avoidance**	Required
8		2	Credit 1	**Preferred Locations**	10
2			Credit 2	**Brownfield Redevelopment**	2
7			Credit 3	**Locations with Reduced Automobile Dependence**	7
	1		Credit 4	**Bicycle Network and Storage**	1
3			Credit 5	**Housing and Jobs Proximity**	3
		1	Credit 6	**Steep Slope Protection**	1
	1		Credit 7	**Site Design for Habitat or Wetland and Water Body Conservation**	1
	1		Credit 8	**Restoration of Habitat or Wetlands and Water Bodies**	1
	1		Credit 9	**Long-Term Conservation Management of Habitat or Wetlands and Water Bodies**	1

Yes	?	No			
24	12	8	**Neighborhood Pattern and Design**	**44** Points Possible	
Y			Prereq 1	**Walkable Streets**	Required
Y			Prereq 2	**Compact Development**	Required
Y			Prereq 3	**Connected and Open Community**	Required
9		3	Credit 1	**Walkable Streets**	12
4	2		Credit 2	**Compact Development**	6
2	2		Credit 3	**Mixed-Use Neighborhood Centers**	4
	7		Credit 4	**Mixed-Income Diverse Communities**	7
1			Credit 5	**Reduced Parking Footprint**	1
2			Credit 6	**Street Network**	2
		1	Credit 7	**Transit Facilities**	1
1		1	Credit 8	**Transportation Demand Management**	2
1			Credit 9	**Access to Civic and Public Spaces**	1
		1	Credit 10	**Access to Recreation Facilities**	1
	1		Credit 11	**Visitability and Universal Design**	1
2			Credit 12	**Community Outreach and Involvement**	2
		1	Credit 13	**Local Food Production**	1
2			Credit 14	**Tree-Lined and Shaded Streets**	2
		1	Credit 15	**Neighborhood Schools**	1

Yes	?	No			
17	8	4	**Green Infrastructure and Buildings**	**29** Points Possible	
Y			Prereq 1	**Certified Green Building**	Required
Y			Prereq 2	**Minimum Building Energy Efficiency**	Required
Y			Prereq 3	**Minimum Building Water Efficiency**	Required
Y			Prereq 4	**Construction Activity Pollution Prevention**	Required

Yes	?	No			
			Green Infrastructure and Buildings, Continued		
5			Credit 1	**Certified Green Buildings**	5
1	1		Credit 2	**Building Energy Efficiency**	2
1			Credit 3	**Building Water Efficiency**	1
1			Credit 4	**Water-Efficient Landscaping**	1
		1	Credit 5	**Existing Building Use**	1
		1	Credit 6	**Historic Resource Preservation and Adaptive Reuse**	1
1			Credit 7	**Minimized Site Disturbance in Design and Construction**	1
2		2	Credit 8	**Stormwater Management**	4
1			Credit 9	**Heat Island Reduction**	1
	1		Credit 10	**Solar Orientation**	1
	3		Credit 11	**On-Site Renewable Energy Sources**	3
	2		Credit 12	**District Heating and Cooling**	2
1			Credit 13	**Infrastructure Energy Efficiency**	1
2			Credit 14	**Wastewater Management**	2
	1		Credit 15	**Recycled Content in Infrastructure**	1
1			Credit 16	**Solid Waste Management Infrastructure**	1
1			Credit 17	**Light Pollution Reduction**	1

Yes	?	No			
4	0	2	**Innovation and Design Process**	6 Points	
1			Credit 1.1	**Innovation and Exemplary Performance**: Provide Specific Title	1
1			Credit 1.2	**Innovation and Exemplary Performance**: Provide Specific Title	1
1			Credit 1.3	**Innovation and Exemplary Performance**: Provide Specific Title	1
		1	Credit 1.4	**Innovation and Exemplary Performance**: Provide Specific Title	1
		1	Credit 1.5	**Innovation and Exemplary Performance**: Provide Specific Title	1
1			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No			
2	0	2	**Regional Priority Credit**	4 Points	
1			Credit 1.1	**Regional Priority Credit**: Region Defined	1
1			Credit 1.2	**Regional Priority Credit**: Region Defined	1
		1	Credit 1.3	**Regional Priority Credit:** Region Defined	1
		1	Credit 1.4	**Regional Priority Credit**: Region Defined	1

Yes	?	No		
67	24	19	**Project Totals (Certification estimates)**	110 Points

Certified: 40-49 points, **Silver:** 50-59 points, **Gold:** 60-79 points, **Platinum:** 80+ points

Appendix B

Critical Industry Topics Summary Sheet

PACE Roundtable Summary Sheet

Session #1: Delivery of Services – *Efficient Use of Integrated Design*

Research Ideas

1. How do the roles of individuals on projects change with a more integrated system?
    a. Do some people take on certain roles and if so how is that decided?
    b. How do you keep everyone informed?
2. Who? When? Where? How?
    a. Who should try an integrated approach?
    b. Difference between IPD and integrated delivery methods
    c. When should it be used?
    d. On what type of projects should it be used?
    e. Colocation
        i. Costs and benefits associated

Session #2: Supply Chain – *Modularization*

Research Ideas

1. To what extent can you modularize components of a building?
    a. Exterior wall panels, MEP, bathrooms, curtain wall, concrete, etc.
    b. Almost a norm now in the mechanical and electrical fields
    c. Safety, quality, schedule
2. Costs vs. Benefits
    a. Do you really save money using prefab?
    b. Can be used as a schedule accelerator but increase price
        i. Dormitory example
    c. Subs working together on modular units
        i. One sub is done, pass it to the next
            1. Risk management of process

Industry member feedback

Which research topic is most relevant to industry? What is the scope of the topic?

Industry member: Raj Vora – Southland Industries

Modularization

- The role it has in an MEP contractor's work
- How it affects the other contractors/GC
- Types of prefab techniques an MEP contractor can take
- The extent to which they can modularize a feature
- Cost vs benefits associated with prefab in MEP
- Thinking about commissioning and quality in a prefab shop
- Delivery system to ensure quick, safe, and effective transportation
- How far ahead you need to know you want to do prefab
    - Start at the beginning of the project or it won't work

Suggested Resources

What industry contacts are needed? Is the information available?

Southland Industries – Raj Vora & Andy Rhodes

- Assist with mechanical and plumbing design, preconstruction, and construction
- Penn State has a good relationship with Southland
- MCAA involvement

Truland – Chuck Tomasco

- Assist with electrical design, preconstruction, and construction
- Good relationship with Penn State
- I interned for Truland in summer 2012