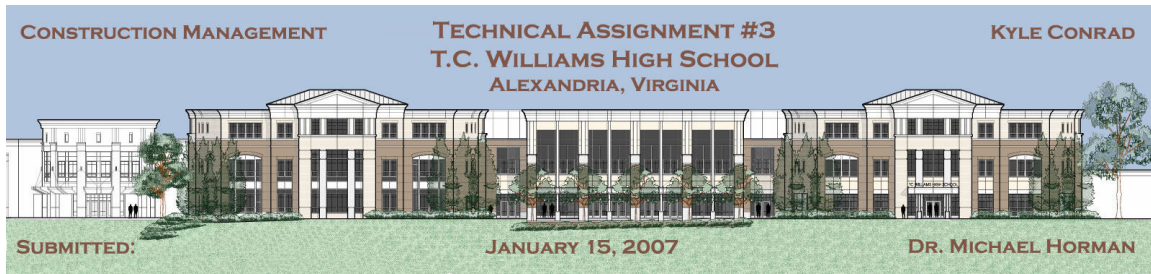


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## A. Executive Summary:

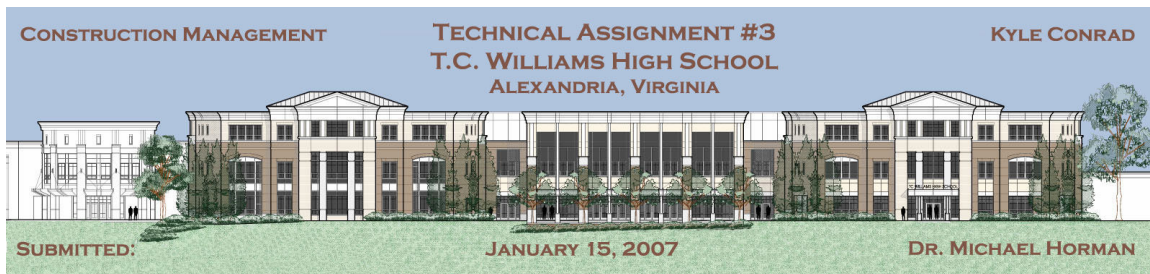
Technical Assignment #3 is designed to generate ideas and develop the proposal for the technical analysis and research performed during the Spring semester. After participating in the 2006 PACE Roundtable event in the fall, a comprehensive list of critical industry issues discussed at the event was written in order to formulate connections to the construction of the T.C. Williams High School Replacement Project.

Acquiring an interest in virtual design, the decision was made to develop a Building Information Model of the T.C. Williams High School and research its effectiveness in value engineering, work sequencing, and site logistics practices. Further research into the unique form of design-build delivery method, utilized on the T.C. Williams High School project, will uncover the risks and advantages to the contracted parties for delivering a project in this manner. The feasibility of employing BIM software on the project will also be assessed.

After revisiting my analysis of the project to date, several areas were identified that had the potential for further investigation into the implementation of alternative construction approaches to the design, planning, and construction of the high school facility. To promote the acceptance of BIM among practitioners in the construction industry, the model will be used to perform and illustrate the technical analyses, revealing a few of the advantages that modeling software has to offer.

The main focus of the analyses will be based on the research and selection of alternative building materials to the durable, yet less than aesthetically pleasing, Concrete Masonry Units [CMU]. The installation of CMU is extremely labor and time intensive and T.C. Williams has an extensive quantity of CMU load bearing and partition walls. Research will focus on the cost, schedule, and performance of the alternative materials in comparison to CMU. The remaining analyses carry the implementation of the alternative materials into the analysis and redesign of the auditorium acoustics and sequencing of schedule activities to promote less congested site conditions.

The owner's expectations and wishes will weigh heavily in the recommendation for an alternative building material, if one proves to be a better value to the owner when compared to the previously designed CMU walls.



## **B. Critical Industry Issues:**

### **Results and Noteworthy Topics of Sessions Attended at the 2006 PACE Roundtable:**

#### **Session 1: Building Respect for Disciplines – MEP Systems**

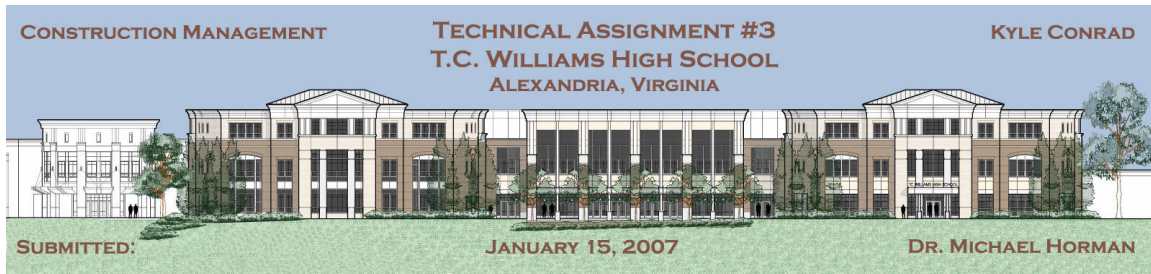
The first morning breakout sessions discussed building systems challenges. Having a profound interest in MEP systems and coordination, the mechanical and electrical building systems session gained my attention. The topics of pre-fabrication, labor saving materials and connectors, owners consideration of energy costs, design standards, specialty consultants, the flexibility in building systems, and simulation tools arose from industry members and concluded with a discussion on the best processes for complex buildings.

The move toward more pre-fabrication of systems reduces the field labor risks and production costs but introduces a new set of challenges. The unit struts that are used in transportation and placement of the racking systems have a tendency to interfere with the surrounding systems or structural components. An increased effort for coordination is needed to assure the assembly fits into place. These systems are cheaper to construct because they are fabricated in a controlled environment, often at lower rates than the prevailing wages required on site. The potential for labor union resistance exists. I was interested to learn that electrical contractors have started pre-fabricating combined panel and transformer units to increase performance.

Industry members seemed to have different views as to the use of labor saving connections like Pro Press. One side claims that the architects and engineers are reluctant to take on the risk of materials that do not have a long track record of performance and that welded connections are bullet proof. Others feel that there is less room for human error and that they are perfect for renovations when burning and fumes become an issue. According to one professional, their durability has been proven for over 25 years in Europe.

Over the summer, I was fortunate enough to witness the implementation of pre-fabricated plumbing assemblies and was able to experience coordination issues first hand. Our fire protection contractors used the Pro Press connections on their sprinkler lines and were able to make connections and adjustments with great speed and ease.

Another issue that was brought up in the session, and was of particular interest to me, was the role of specialty contractors. Control over these contractors is often being retained by the owner which results in added difficulty to the coordination of various systems by the general contractor. Areas are frequently left incomplete for the specialty contractors to perform their work, at a date that is most convenient for them, and then the subcontractor returns at a later date to finish their scope of work.



From personal experience, the added frustration and cost due to the delay of work and rework can be significant. This can result in an over sizing of building systems to accommodate the unknown requirements of these specialty contractors and consultants.

Owners are also beginning to make decisions based on the energy cost savings of their buildings a lot earlier in the process. Building owners are being rewarded by grants and tax incentives for actively pursuing buildings with guaranteed energy savings. Designers are finding it possible to minimize energy usage by correctly sizing equipment and are getting traction with the codification of ASHRAE standards and the push for LEED ratings.

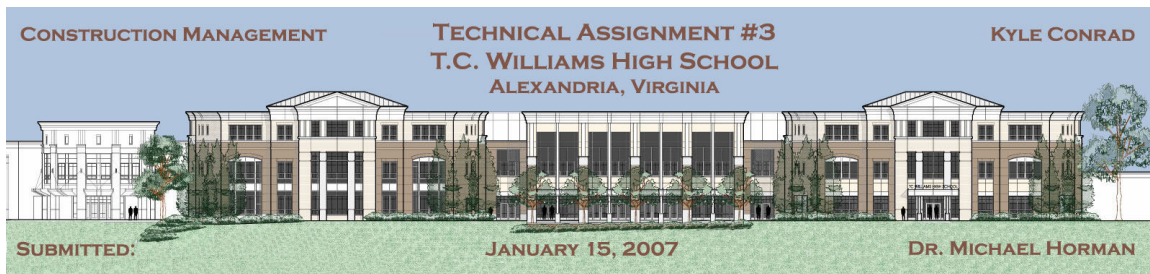
The flexibility of building systems was addressed through the issues surrounding under floor systems. Industry members are concerned for the contamination of floor systems due to debris and moisture associated with the delays of building dry-in due to the extended selection process of exterior building materials. Under floor systems also involve different sequencing and detailing that can lead to increased complications in scheduling. The initial beliefs of flexibility are being lost in the long run as floor plenums are being packed with various systems, leaving no room for expansion.

Simulation tools are not being requested by most owners. Industry members agreed that recent graduates, which have been trained in the use of these tools, need to take the initiative and get the ball rolling. As a general consensus, no one looks at the big picture. Contractors are more interested in meeting their own schedules and finishing their scope of work. The owner will need someone to pull the resources and handle the coordination of simulation tools and develop a project assumption list to get all involved parties on common ground.

As buildings become more complex the owner's level of interaction is the key to a successful project. The owner must understand the impact of the requirements being placed on the building systems to make informed decisions.

## **Session 2: Team Dynamics and Communication with BIM**

The focus of our second breakout session was to be team dynamics and communication with building information modeling (BIM). The relationship improvement opportunities addressed focused on the models ability to improve communications by removing the negative viewpoints, 'less conflicts with less conflict'. A more respectful relationship will arise between the architect and contractors as the knowledge gap is bridged between the construction and design. This realization tied in nicely with the building respect theme of the 2006 PACE Roundtable. The owner is also brought into the equation when considering the use of the model for operational and maintenance purposes.



The majority of the session was spent introducing the concepts behind BIM to industry members. Several professionals were having a difficult time buying-in to the implementation of BIM. With the resistance encountered in a room of industry members with similar backgrounds, the challenges of implementing BIM into the construction industry became evident. Some members were blinded from the big picture of the project by their inability to see a direct cost savings for their company. The ability of BIM to identify system conflicts prior to putting work in place, alone, significantly reduces cost due to the avoidance of construction delays encountered in the field and rework of the systems.

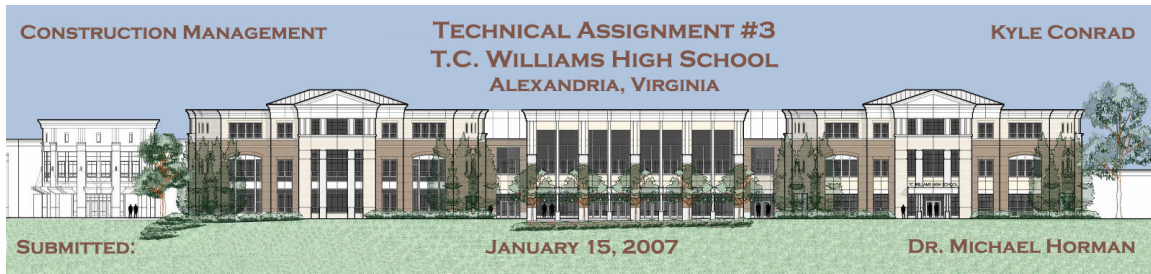
### **Session 3: Building Respect for Disciplines – MEP Systems**

Deeply rooted in the building respect theme, the final session focused on building respect with owners and operators. Honesty and following through to make and keep commitments were the key techniques to securing a good working relationship and earning respect. When problems arise, being able to provide solutions or merely an indication that you are working on a solution and being able to communicate the plan goes a long ways with the owner.

Several indicators of a healthy relationship were posed: communication attitude, obtaining return clients, the presence of a free flow of information, and being viewed as a predictable outcome (go-to guy). The individuals within an organization determine the level of respect for a company. Respect will eventually develop into trust as the relationship continues to grow. However, the respect of an owner can be lost. It is imperative that the owner's expectations be managed. Remember that even though delivering the project on time is important, it is the smaller commitments along the way that make the difference. The contractor has to prove to the owner that they are looking out for the owner's best interests. Owners realize that contractors are in the business to make a profit but when both parties realize that the ultimate goal is the best possible project, the relationship will flourish.

### **Application to T.C. Williams High School Replacement Project:**

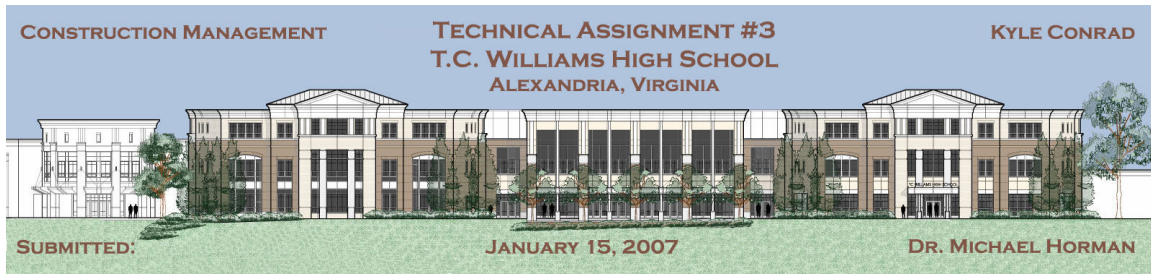
The Alexandria City Public Schools showed a tremendous interest in reducing their new facilities impact on the environment and energy costs. Enthalpy wheels were implemented in the AHUs to recover total energy. To transform the school into a living laboratory for the students, a control panel was integrated into the court commons area to keep student informed of the energy loads being consumed by the building. A further analysis into the mechanical systems of T.C. Williams should provide additional incite into the measures taken by the owner to build an energy friendly facility.



Hensel Phelps Construction Company is committed to developing strong and lasting relationships with their clients. They understand that it is the owner who has contracted them to provide construction and project management services and needs to be satisfied with their substantial investments. In fact, the unique project delivery method proves their commitment to owner satisfaction. After the project reached 100% design, the delivery method was reconfigured so that Hensel Phelps accepted full responsibility and the risk associated with errors and omissions in the contract documents. Hensel Phelps also went through an extensive value engineering and management period and proceeded to oversee all redesign of the facility to implement their V.E. ideas.

#### **Key Contacts from 2006 PACE Roundtable:**

At this years Roundtable event, I had the opportunity to have a more in-depth discussion into critical issues with two industry professionals: Jeremy Sibert, a Project Manager with Hensel Phelps Construction Company and Michael Pittsman, the Vice President of the base building division with James G. Davis Construction Corporation. Jeremy is currently working on the Social Security Administration Operations Renovation project in Baltimore, Maryland. We discussed the problems that we foresee in the implementation of BIM into the industry. Hensel Phelps recently started their first project that will utilize BIM from conception through the construction process. We will both be interested to see the successes and difficulties of the project as they unfold. Michael is involved with the below-grade bus depot and visitor center at the Washington National Cathedral in Washington, D.C. I was most impressed by our interaction during the team building event. A true team arose out of the competition. Even in the brief period that was spent together, everyone's ideas were encouraged and considered in the teams approach to the planning and construction process. We may not have had the tallest structure, but the activity was encouraging and a real success.



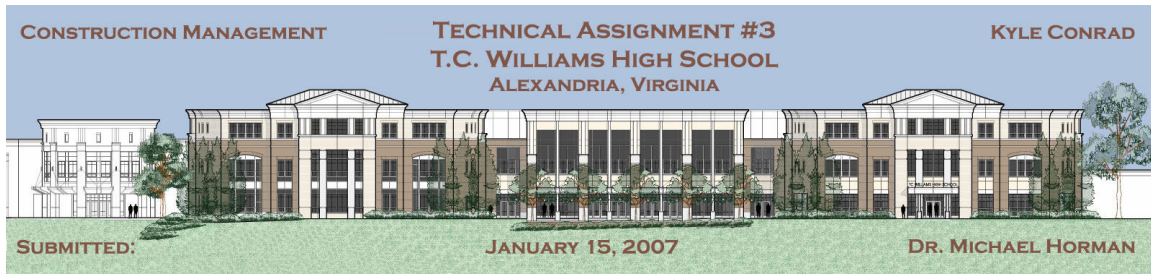
### **C. Critical Issues Research Method:**

#### **Effectiveness of Building Information Modeling [BIM] in Value Engineering [VE], Work Sequencing, and Site Logistics:**

The development of Building Information Modeling is slow to gain acceptance into the building construction industry. Recently, the General Services Administration [GSA] has mandated that all the new construction projects designed by its Public Building Services, starting in the 2007 fiscal year, are required to utilize BIM in the design phase of the project. After attending the discussion sessions at the 2006 PACE Roundtable and first hand interviews with prominent companies in the industry, a broad spectrum of company knowledge of BIM has become evident. A few companies have advanced to the point where the majority of their projects capitalize on BIM tools from start to finish while others acted as though they were hearing about BIM for the first time. Until the benefits of BIM are clearly understood and accepted by industry professionals, hesitation to implement the process will exist and construction projects will continue to incur unnecessary rework costs.

By researching, developing, and presenting the potential benefits of BIM in processes of value engineering, work sequencing, and site logistics, the exposure of industry members to the effectiveness of BIM in the construction of a project will aid in alleviating some of the hesitation of implementing BIM into their own projects. While the acceptance of BIM into the construction industry will not come overnight, graduating college students that have had experience with BIM pose to be the greatest source of opportunity for construction industry companies to enter into the new era of construction.

Harnessing the knowledge of the Penn State Architectural Engineering faculty members, recent graduates, current students, and industry professionals interested in the development of the virtual design of construction projects, a building information model will be developed, with BIM software, in order to perform and present the technical analyses found in **Section E** of this document, inevitably expressing the effectiveness of BIM in these construction processes.



### **Project Delivery Method:**

The T.C. Williams High School Project was contracted under a traditional design-bid-build delivery method and reorganized into a unique form of design-build as described in detail in **Section D of Technical Assignment #1**. Further investigation into the project delivery method will reveal the risks and advantages of the contracted parties after the reorganization. In order to gain insight into the project specific delivery method, consultations with the project's general contractor will take place. Literary reviews will also be performed to acquire additional information from other projects that have been delivered through similar methods.

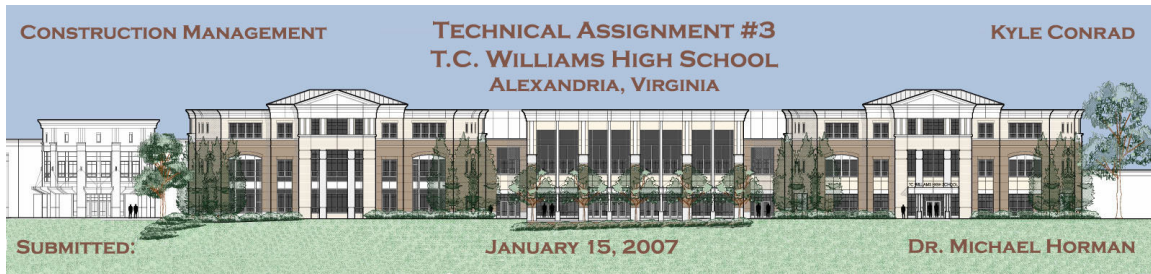
After consulting my industry professional contacts, as well as knowledgeable faculty members, the feasibility of implementing BIM on a project delivered through this method will be reported.

### **D. Problem Identification:**

#### **Value Engineering**

- There is an extensive amount of masonry work involved in the construction of T.C. Williams High School. The majority of the exterior walls, interior partitions, and façade require skilled masonry labor. Masonry is labor and time intensive and the schedule may benefit from the implementation of prefabricated materials that are durable and promote an aesthetically pleasing learning environment.
- The showpiece of a high school is often its auditorium and lobby area. Members of the community are drawn into this facility for school programs and should feel welcomed and comfortable in the environment. An analysis of the lighting and acoustical systems could expose the potential for value adding components.
- A cistern was constructed to capture rainwater from the expansive roofing system to be circulated through non-potable systems within the facility. I am interested in determining the life cycle cost of the cistern based on the average annual rainfall in Alexandria and identifying additional uses of the system to reduce the payback period and capitalize on its potential for saving money on utility fees. By establishing the life cycle cost, the decision can be made to either eliminate the construction of the cistern or expand the cistern's intake to additional roof area based on the payback period of utility costs.





## **Constructability**

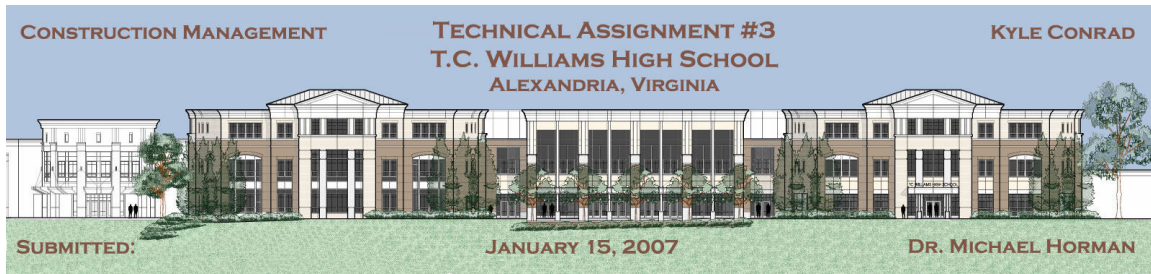
- While performing the detailed structural steel take-off, a complex structural system was uncovered. There are a variety of shapes, sizes, and lengths of members that will increase the need for management to ensure the appropriate members arrive and are installed in the designated sequence. The structural members need to be designed with more typical member sizes to reduce confusion in the field and ensure the availability of structural members when they are required.

## **Site Layout**

- The sequence of workflow cuts the contractors off from their current staging area requiring the materials to be transported around the constructed areas of the building, when they are ready to be installed. Contractors are limited to hauling the materials around the east side of the building or the public access roadway adjacent to the site. The area between the site fence and building is minimal resulting in a congested building material transportation lane. By resequencing the workflow, contractors can work toward their staging area with an unobstructed flow of building materials to the location of installation.

## **Miscellaneous**

- On complex projects and projects of grand scale, the drawing sets can become intensive and require a great deal of cross referencing between drawings. The development of a BIM would prove to be extremely valuable. After maneuvering to the location of interest in the model, all of the information is available at you fingertips by selecting the desired object layers.
- The project was delivered in an unusual method. A further investigation into the development and implementation of the contractual agreements, organizational structure, and operational procedures will expose the opportunities and threats associated with the unique style of delivery method.
- The fire suppression system is a wet pipe system. With all the computer labs and expensive educational equipment, another type of system may be beneficial with the high level of curious and experimental adolescents occupying the spaces.



## **E. Technical Analysis Methods:**

### **Analysis # 1: Alternative Building Materials to CMU**

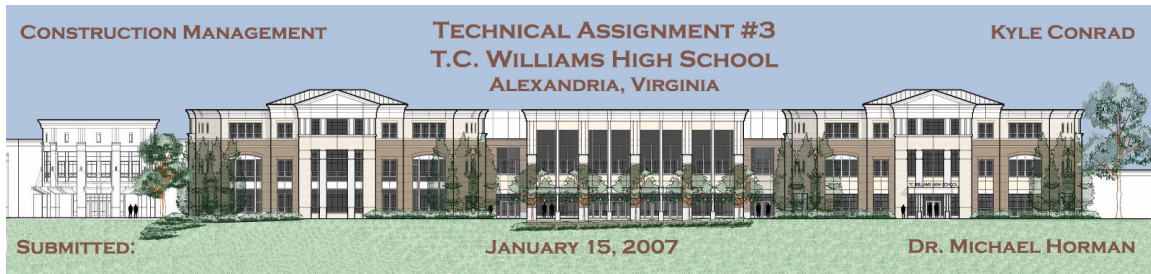
School facilities commonly use CMU as a building material due to its durable characteristics and low material cost. However, the installation of CMU is extremely labor and time intensive and is less than aesthetically pleasing. Research into alternative building materials will be performed to obtain suitable selections for value engineering analyses. Value engineering is often confused with cost cutting. In actuality, VE aims to provide the owner with the best product for the amount of money allocated.

Materials will be analyzed against cost, schedule impacts, heat transfer, sustainability, and quality. Material costs are dependent on initial costs as well as schedule delays due to the availability of the material and labor. Transportation costs may increase the cost of the material if the manufacturer or supplier is removed from the area where the facility is being constructed. The erection speed of the material can have a significant impact on labor savings unless the subcontractors selected to perform the work are unfamiliar with the material, resulting in a substantial learning curve. Cost savings can be acquired through a reduction of heating costs with materials that have a higher resistance to heat transfer. Since the Alexandria City Public Schools are interested in constructing a building that has a low impact on the environment, the sustainability of the materials will be considered. Interest will be expressed in materials that would improve the quality of the students' learning environment while maintaining the durability obtained with CMU.

BIM will be utilized to demonstrate the ease of performing an alteration to the original contracted model as well as quantity takes-offs for the estimate comparison between materials. Schedule impacts will also be considered and displayed in the model.

### **Analysis # 2: Auditorium Acoustics**

In continuation of the analysis performed researching alternative building materials, an acoustical analysis of the auditorium will be performed. High quantities of sound absorbing materials were added to reduce the level of noise in the CMU enclosed space. By selecting a material with sound absorbing characteristics, value would be added to the space with the potential of saving money by reducing the need for additional sound panels.



A new acoustical design will be developed using the BIM software and a detailed analysis of the room absorption will be calculated to acquire the optimum reverberation time for a high school auditorium. Careful consideration to sound paths will be considered to control echoes in the facility and transmission loss analysis will ensure background noise is maintained at an acceptable level.

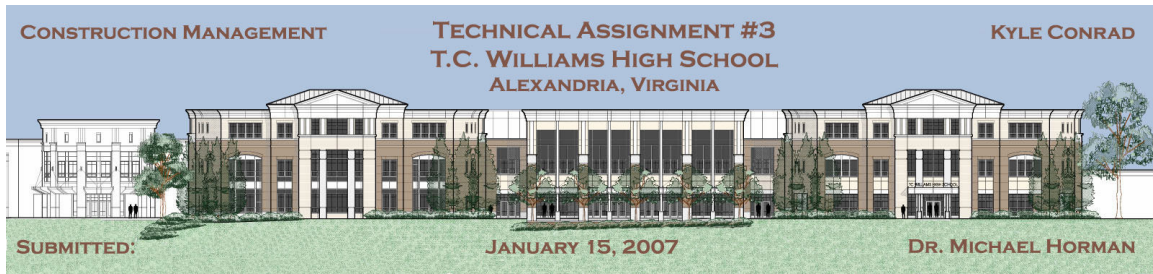
### **Analysis # 3: Work Sequencing and Site Logistics**

Due to the extensive concrete block work in the gymnasium, automotive strip, kitchen, and auditorium the CMU wall construction begins in the early phases and continues long into the project duration. The material storage and staging area is in the far Southeastern corner of the site and all of the work is progressing in a Southeast to Northwest direction (**described in detail in Section C of Technical Assignment #2**). Ultimately, the flow of work makes transportation of building materials toward the end of the project more congested.

Using the alternative building materials selected in analysis #1, the workflow will be resequenced to alleviate some of the site congestion due to the transportation of building materials. With the quicker erection time of prefabricated materials, the work activities in the aforementioned areas will not be require to begin as early in the construction process, allowing for easier access to the material storage and staging areas.

BIM software will be used to develop and visualize the resequencing of schedule activities by detecting improper sequencing of work activities as the duration of the alternative building materials are integrated into the design of the facility. A three dimensional representation of the site plan will be included in the demonstration to enhance the visualization of site constraints.

The recommendation for building materials will be made after the investigation of the areas of analysis discussed above and careful consideration into the goals and desires of the owner.



## F. Weight Matrix:

During the course of the Spring 2007 semester, the technical analyses discussed above will be developed and incorporated with the Building Information Model. The predicted breakdown of my allocation of time and efforts has been provided in **Table 1** below.

DESCRIPTION	RESEARCH	VALUE ENGINEERING	CONSTRUCTABILITY REVIEW	SCHEDULE REDUCTION	TOTAL
Alternative Materials	5 %	10 %	5 %	5 %	25 %
Auditorium Acoustics	5 %	10 %	0 %	0 %	15 %
Sequencing & Site Logistics	0 %	0 %	10 %	5 %	15 %
Contracting Method	10 %	0 %	0 %	0 %	10 %
BIM	10 %	10 %	5 %	10 %	35 %
<b>Total</b>	<b>30 %</b>	<b>30 %</b>	<b>20 %</b>	<b>20 %</b>	<b>100 %</b>

**Table 1. Allocation of Time for the Spring 2007 Semester.**