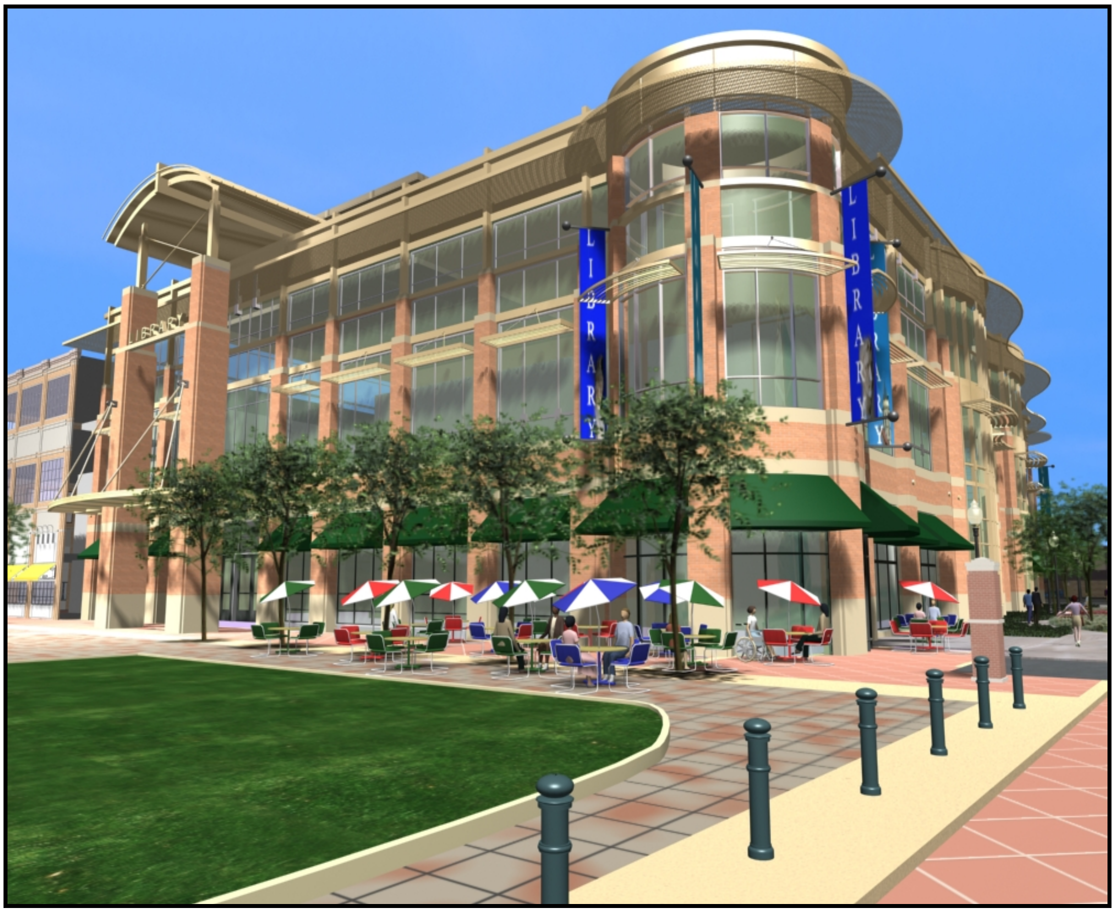
The Rockville Library Final Thesis Proposal



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Construction Management
Advisor: Dr. Messner

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Executive Summary

The following report is a final investigation intended to fully evaluate the Rockville Library's design, construction, and future operation. Each area of this building's life cycle is examined in order to determine if improvements can be made. The following proposals for building improvement include alternative structural systems, recommendations on using innovative technology, designing for future deconstruction, and utilizing environmentally friendly building components. These recommendations are intended to reflect savings in all aspects of the Rockville Library's life-cycle.

The four proposed investigations share the goal of creating some form of cost savings. Some of these savings are directly related to the current construction process and can be priced and examined in a value engineering analysis. Others savings are indirect and create benefits in construction schedule or future operations cost which ultimately leads to lower cost. Each proposal also intends on being conscious of both sustainability and environmental concerns in order to create a building that does not negatively impact the environment.

Each proposal was thoroughly investigated and adapted to the Rockville Library. Often the proposals revealed relevant cost savings and increased efficiency of the construction and operation processes. However, not all investigations met each of the goals intended at the onset of this thesis proposal. When this happened, shortcomings were discussed instead of ignored to show the lessons learned. Each proposal was a significant part of the overall thesis analysis that accomplished the goal of creating savings and justifying their place in this building's life cycle.

The Rockville Library

Tom Caldwell
Construction Management

Library Statistics

Location:	Rockville, Maryland
Completion:	June 2006
Project Cost:	26.3 million
Size:	102,400 ft^2, 3 stories
Usage:	Public Library Office/Retail Space

Structural Features

> structural steel building frame
> curtainwall building envelope
> 3 story main entrance canopy
> cylindrical towers at 2 main corners

Mechanical Features

> utilizes Automatic Temperture Control/Energy Management Sys.
> runs on 7 interior AHU's

Electrical/Lighting Features

> 960 kVa utility transformer, 8 total
> 480/270 V, 3 phase 4 wire system
> 50 footcandle lighting demands met w/ flourescent T8 4 ft. linear lamps

Unique Features

> design a representation of the double helix shape of a DNA strand
> 2 story elliptical staircase in front lobby
> bending and bowing building walls follow street and walkway curvatures

Project Team

Owner:	Montgomery County
Architect:	Grimm & Parker Arch.
Civil Engr:	A. Morton Thomas
Structural Engr:	CEI Engineering
MEP Engr:	Gipe Associates
Interiors:	Hodkinson Associates
General Contractor:	Forrester Construction

For more visit : http://www.arche.psu.edu/thesis/eportfolio/current/portfolios/tmc239/

<u>Local Conditions</u>

Building construction is taking place in the renovation area of the new Rockville Town Center. This site has already been developed from the previous construction of a mall. The site in which the Rockville Library will be built was once a parking lot so the area is cleared and leveled. Soil boring samples were taken on site and compared to previous boring tests from construction on site years ago. The soil borings went to 30' deep and classified the soil as silty sand and sandy silt with small rock fragments under the layer of asphalt and gravel present from the parking lot. Also, no major site dewatering or leveling would be needed due to previous construction on the site, so excavation was expected to have no delays and take only three weeks to complete.

There is also a lot of room for site parking, crane location, and excavation since the site is very large and encompasses more than just the Rockville Library site. The entire town center is 72 acres large and is completely closed off due to construction on the entire area. Since the construction is phased around the plaza, at any time there are open areas for equipment storage, staging, and parking. This takes a lot of burden off the project manager with all this space to work with. However, there needs to be constant communication with other crews on site to ensure the use of certain spaces. If there isn't a definite plan in place two different crews may try to use the same spot for placing resources which may cause disputes and congestion.

Current Site Conditions from Live Webcam

Recycling in the area unfortunately is not very present on this project. Forrester Construction is trying to recycle whatever they can save however; it isn’t a major concern in the construction process. Local conditions are favorable for recycling though with gypsum, scrap metal, wood, and general recycling plants within 30 miles of the site. It just isn’t in the scope of the project to worry about coordination of recycling. Instead the focus of construction was on producing a quality building.

Typical construction methods in Rockville vary due to the age of the city. Development of the downtown had not taken place since the 1970’s and with the construction of this town center there is an opportunity to change the typical building standards. Most surrounding buildings are not large and made of cast-in-place concrete and steel framing. The building of the town center is similar in structure to surrounding building, but place a lot more emphasis on exterior masonry and fixtures which bring a needed aesthetic tone to the downtown. In Rockville there is often not a lot of room for construction due to the crowded urban atmosphere so site management is a must on these construction projects. And as on most urban projects site security and safety is a must due to the amount of pedestrians present at all times. Overall Rockville has a lot of positives for building construction with its flat landscape and conducive soils, yet dealing with the crowded downtown area makes the need for site management more essential.

Building Systems Summary

Structural Steel Framing

The Rockville Library is supported by a system of structural steel columns, beams, and girders. This steel skeleton consists of beams sizes mainly being W 16x26, 18x35, and 12x16, while girder sizes are mostly W 21x57 and 24x62. Steel columns normally rise through all three building stories and are typically sized at 24”x36” piers with 9’x9’ footings. Lateral bracing is used to support frame columns, connected by full penetration welds. Steel beams are aligned uniformly at 8 feet apart, running east/west along the narrower length of the building. Girders run through along the wider length and are spaced based on the required loading of the area. Where more support is needed like in mechanical rooms and computer labs, girders and beams are spaced closer together to handle the load. For the majority of the library, which are office spaces and reading rooms, less support is needed and more spacing can be given to steel beams and girders. In order to erect the steel a single truck mounted, hydraulic, with a 100 ton capacity crane is used. This type of crane fits the job since the structure is not too tall for a truck crane, there are no overly heavy objects to lift, and the site is small enough for the crane to move and reach every area of the building. The truck crane is affordable and can be moved to neighboring sites to aid in the construction of the entire building complex.

Cast-In-Place Concrete

Cast-in-place concrete is used to form the foundation and floor slabs for the Rockville Library project. The building foundation and roof consists of 3000-psi normal weight concrete reinforced with ASTM A/615A 615M, Grade 60, deformed rebar and W2.1xW2.1 weld wire fabric. Reinforced 3000-psi concrete is used as footings for masonry units and structural steel as well. Lightweight 3000-psi concrete is used for the second and third floor slabs. These slabs are thin measured in ay 5” thick on the 1st and roof levels, and 3” on the second and third floors. They are sized so thin not only because of structural steel reinforcement, but the lack of dead and live loads in most of the areas

building space because of open reading areas and conference rooms. The only dead loads that the structure is concerned in supporting are bookshelves and mechanical units on the upper floors. Live loads shouldn't be overwhelming to the structure either since the public library doesn't expect there to be an abundant number of occupants in the space at any one period of time. Concrete is distributed by pump from a mobile unit that easily spreads concrete to all areas of construction. This is a more efficient method of distribution than a crane and bucket since concrete can be placed in specific locations even with a ceiling cover so construction continue upwards before the slabs are finished on the floor below.

Mechanical System

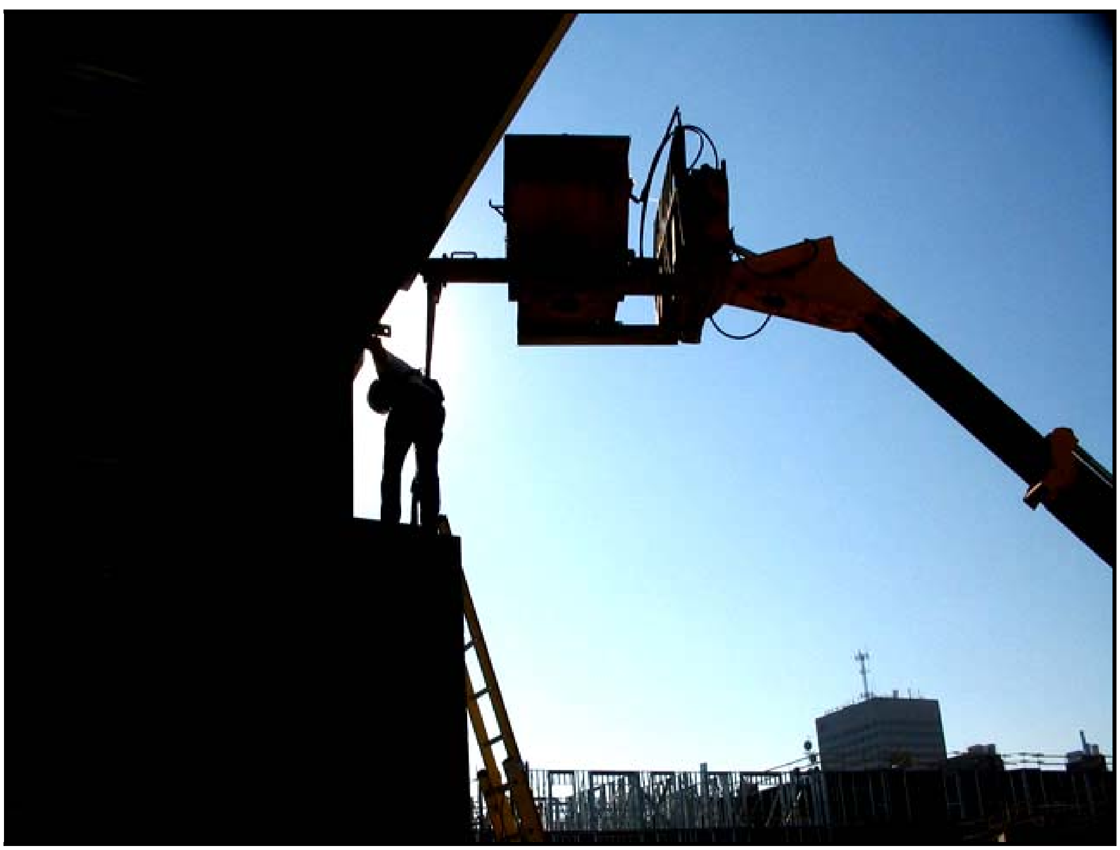
The mechanical systems of the Rockville Library are designed to create spaces that are flexible, functional, energy efficient, and respond to the needs of the facility. This system will be controlled by an Automatic Temperature Control/Energy Management System, which will create the appropriate thermal environment for all building spaces. The HVAC system consists of 3 different types of distribution methods selected based on the size and desired noise levels of each building space. In the stack area a constant volume terminal reheating system is used, office areas use a variable air volume system, while in the meeting rooms conditioning units circulate airflow. The building will be heated by means of a Central Heating Water Plant with a heating water circulating system serving hot water heating coils located in air handling units, unit heaters, convectors, and other parts of the HVAC system. The library will be cooled through the use of a central chilled water plant with a chilled water circulating system serving chilled water coils located in air handling units. In total the HVAC system uses 7 air handling units; 2 on the roof with another 5 located around the building. Ductwork is mainly made of galvanized steel rectangular duct that is concealed by a ceiling grid. In general the mechanical system is concealed from view yet is made easily accessible for maintenance through their centralized locations. The majority of mechanical equipment is stored in mechanical closets on the 2nd and 3rd floors including the boilers, hot water generators, pumps, air handling units, and the Automatic Temperature Control/Energy Management System. The remainder of major mechanical units is located on the roof including cooling towers, air handling units, and circulating fans. For fire suppression Viking Microsoft sprinkler heads with recessed excursion panels are placed within the ceiling grid of all areas of the library. These sprinklers distribute water in case of a fire using a basic wet pipe system through most areas of the building. On the lowest building level a quick response system is put into place by integrating smoke detectors with sprinkler heads to prepare the sprinklers for a possible emergency situation. Water is dispersed into the sprinkler pipes where they await for the heads to be activated by heat indication at which point they release onto the fire. Standpipes are also present in the stairwells of the building making this project completely consistent with all local fire codes.

Electrical System

The electrical system for the new Rockville Library is suitable for a state-of-the-art learning center. The system is set up to support several lighting and power needs from all the computer labs running through the building. The main transformer is 960 kVa and there are 8 transformers located throughout the building. The power is a mostly 480/277 V with a 3-phase 4-wire system. The lighting voltage primarily being 480/277 V and the receptacles are 208/120 V. In general a lot of power is needed to ensure the lighting and computer loads of this facility are taken care of. Main panelboards are located on every floor in central and isolated utility closets for easy maintenance.

Masonry

The Rockville Library makes use of both load bearing and veneer masonry. Concrete masonry units enclose the building supported by steel reinforcement bars and concrete formwork. 4” interior layers and 12” exterior layers are grouted into the building walls on the western and northern building elevations. Freestanding CMU units are bonded with steel #5 rebar to concrete footings on parts on the southern and western building ends. Brick veneer decorates the building exterior around the southern and eastern curtainwall areas and are placed by steel tubular scaffolding.



Curtainwall

The curtainwall system is being prefabricated and delivered to the site due to the complexity of its design. The curtainwall is made primarily of brick veneer and glass panels with aluminum paneling outlining the windows. It is being fabricated by Kawneer, manufactured in New Hampshire by a company called Galaxy Glass & Aluminum Inc. and is due to be installed in November. Curtainwall erection should be rather complicated due to several curved sections that match the double helix representation of the building's design. However, using a truck crane and having the site prepared and coordinated for delivery of the curtainwall sections should allow for a faster and simpler assembly.

Support of Excavation

Previous to building construction the site was a parking lot for a local mall. The mall was demolished before building construction and the site was prepared for building construction as apart of the town center development. Soil was analyzed and determined that shallow excavation and little to no dewatering was required due to previous development on site. The main concern was realizing where existing utilities were located and how to properly tie-in these resources to the site. Excavation is slopped since it is considered to be shallow enough not to require shoring. There is enough room on site to allow for slope excavation and grouting protects foundation footings from any water that still exists on site.

Detailed Project Schedule

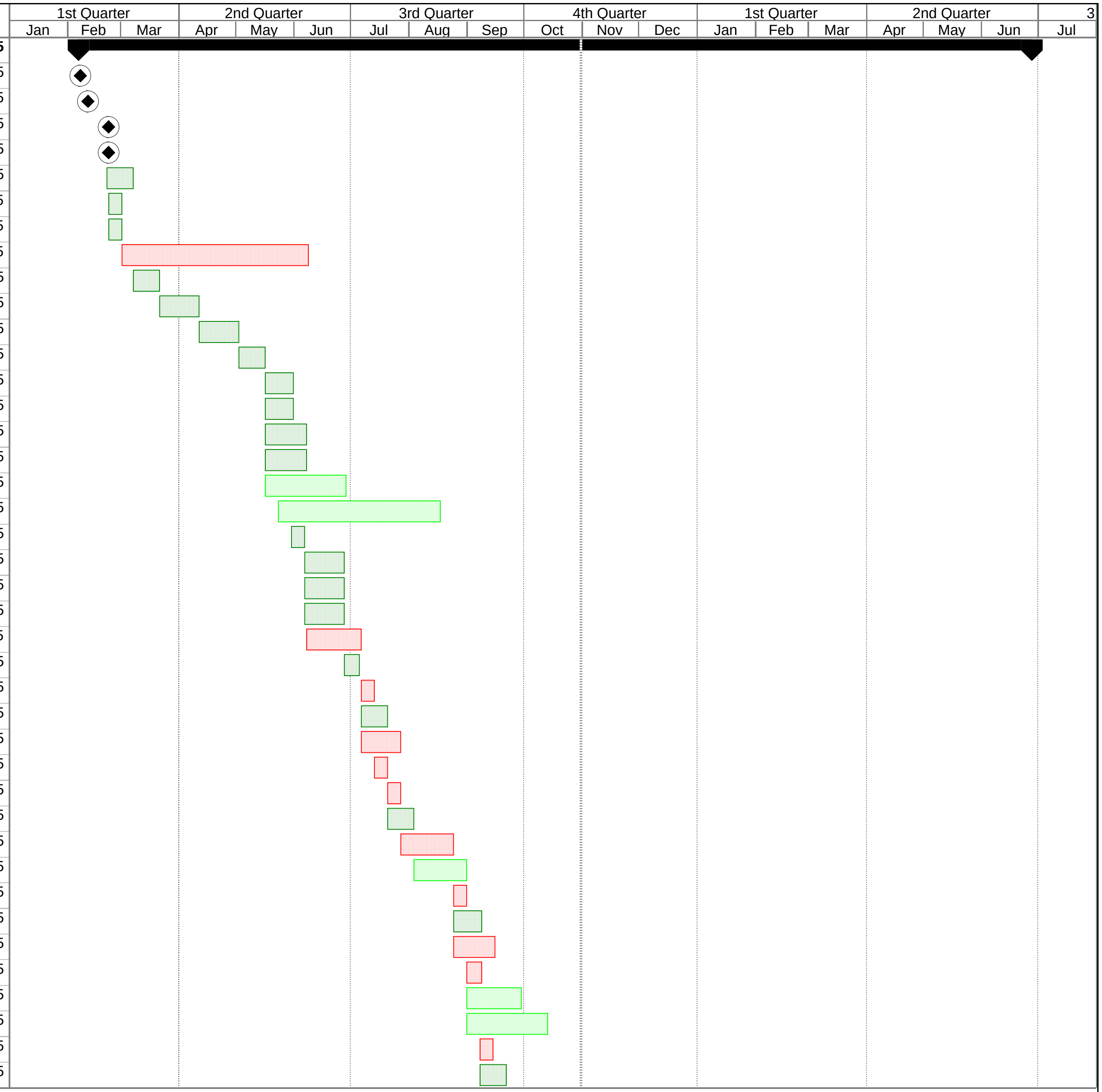
The Rockville Library project depends on coordination of several trades in order to assure the timely completion of the project. The project is broken into several different systems which I have coordinated above. These trades must interact together on several different occasions and observe the schedule frequently in order to understand their space limitations and time management. Landmarks are also noted in the project schedule by circled markers which indicate the major events that will affect the overall project.

Green	**Excavation/Foundation**
Red	**Structural System**
Lime	**Building Envelope**
Aqua	**1st Floor Coordination**
Teal	**2nd Floor Coordination**
Fuchsia	**3rd Floor Coordination**
Yellow	**Joint Floor Coordination**
Blue	**Mechanical/Specialty Systems**
Olive	**Close Out**

Overall, the construction sequencing on the Rockville Library Project is very straightforward. Excavation and foundations begin after notice to proceed is given and site mobilization is completed. After steel fabrication is completed and the foundation is prepared for steel erection, then the building can be put up. From there as the structure is assembled, the building envelope can be constructed so that after steel erection is completed, the envelope is not far off from being sealed. Throughout this process HVAC, piping, electrical, and fire protection systems can be installed on each floor. After climate control is obtained, interiors can begin which continues on each floor until project close out can begin.

The main coordination issues are with the foundation, structural, and building envelope systems at the beginning of the project. All 3 of these systems are being constructed in sequence in order to try and obtain a building seal as fast as possible. Afterwards MEP trade coordination and interiors are the biggest issue. These trades will be working side by side on each floor frequently and paying close attention to sequencing is a must.

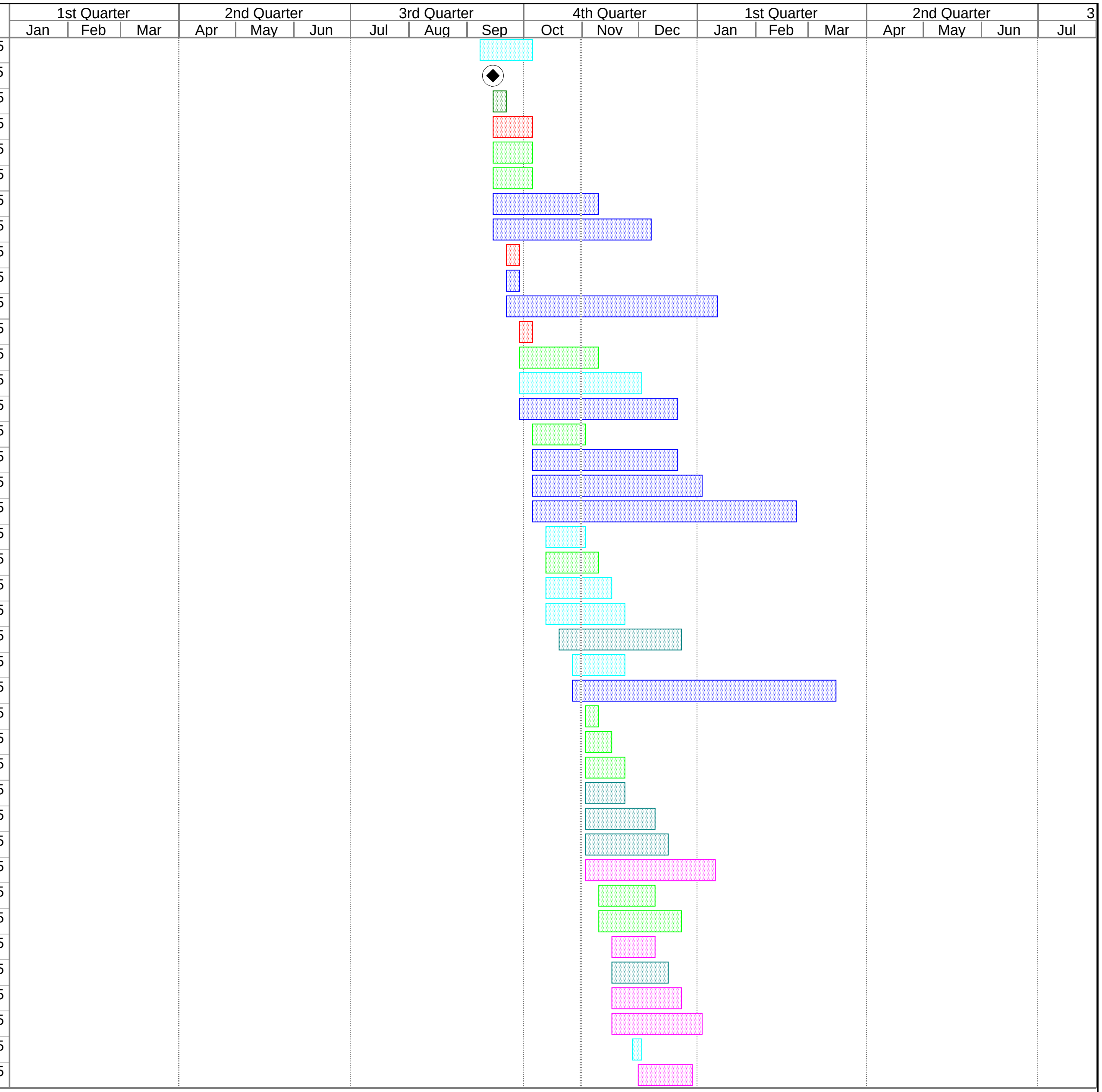
Task Name	Duration	Start
Rockville Library	**354 days**	**Mon 2/7/05**
Recieve Contract	1 day	Mon 2/7/05
Obtain Permits	1 day	Fri 2/11/05
Mobilize To Site	1 day	Tue 2/22/05
Notice To Proceed	1 day	Tue 2/22/05
Rebar Fabrication	10 days	Tue 2/22/05
Install Sediment Control	5 days	Wed 2/23/05
Install Site Fencing	5 days	Wed 2/23/05
Fabricate Steel	70 days	Wed 3/2/05
Deep Footings SW & NW	10 days	Tue 3/8/05
Perimeter Footings/Walls South	15 days	Tue 3/22/05
Perimeter Footings/Walls North	15 days	Tue 4/12/05
Interior Footings/Walls South	10 days	Tue 5/3/05
Below Grade Plumbing South	10 days	Tue 5/17/05
Below Grade Electrical South	10 days	Tue 5/17/05
Interior Footings/Walls North	15 days	Tue 5/17/05
Below Grade CMU South	15 days	Tue 5/17/05
Cast Stone Fabrication, Delivery	30 days	Tue 5/17/05
Curtainwall Fabrication, Delivery	60 days	Tue 5/24/05
Elevator Piston Shaft	5 days	Tue 5/31/05
Below Grade Plumbing North	15 days	Tue 6/7/05
Below Grade CMU North & East	15 days	Tue 6/7/05
Below Grade Electrical North	15 days	Tue 6/7/05
Set Southern Steel Decking & Columns	20 days	Wed 6/8/05
Perimeter Foundation Drain	5 days	Tue 6/28/05
Pour 2nd Floor South Slab On Decking	5 days	Thu 7/7/05
Pour Slab On Grade South	10 days	Thu 7/7/05
Set Eastern Steel Decking & Columns	15 days	Thu 7/7/05
Pour 3rd Floor South Slab On Decking	5 days	Thu 7/14/05
Pour South Penthouse Slab Pads	5 days	Thu 7/21/05
Backfill Perimeter Walls South	10 days	Thu 7/21/05
Set Northern Steel Decking & Columns	20 days	Thu 7/28/05
Masonry, Cast Stone Installation, South	20 days	Thu 8/4/05
Pour 1st Floor Slab North, East	5 days	Thu 8/25/05
Pour Slab On Grade North	10 days	Thu 8/25/05
Set Final Steel Columns & Decking	15 days	Thu 8/25/05
Pour 2nd Floor Slab North, East	5 days	Thu 9/1/05
Glazing Panel Systems, South	20 days	Thu 9/1/05
Masonry, Cast Stone Installation, East	30 days	Thu 9/1/05
Pour Penthouse Slab North	5 days	Thu 9/8/05
Backfill Perimeter Walls North	10 days	Thu 9/8/05



Project: Rockville Library
Date: Mon 10/31/05

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

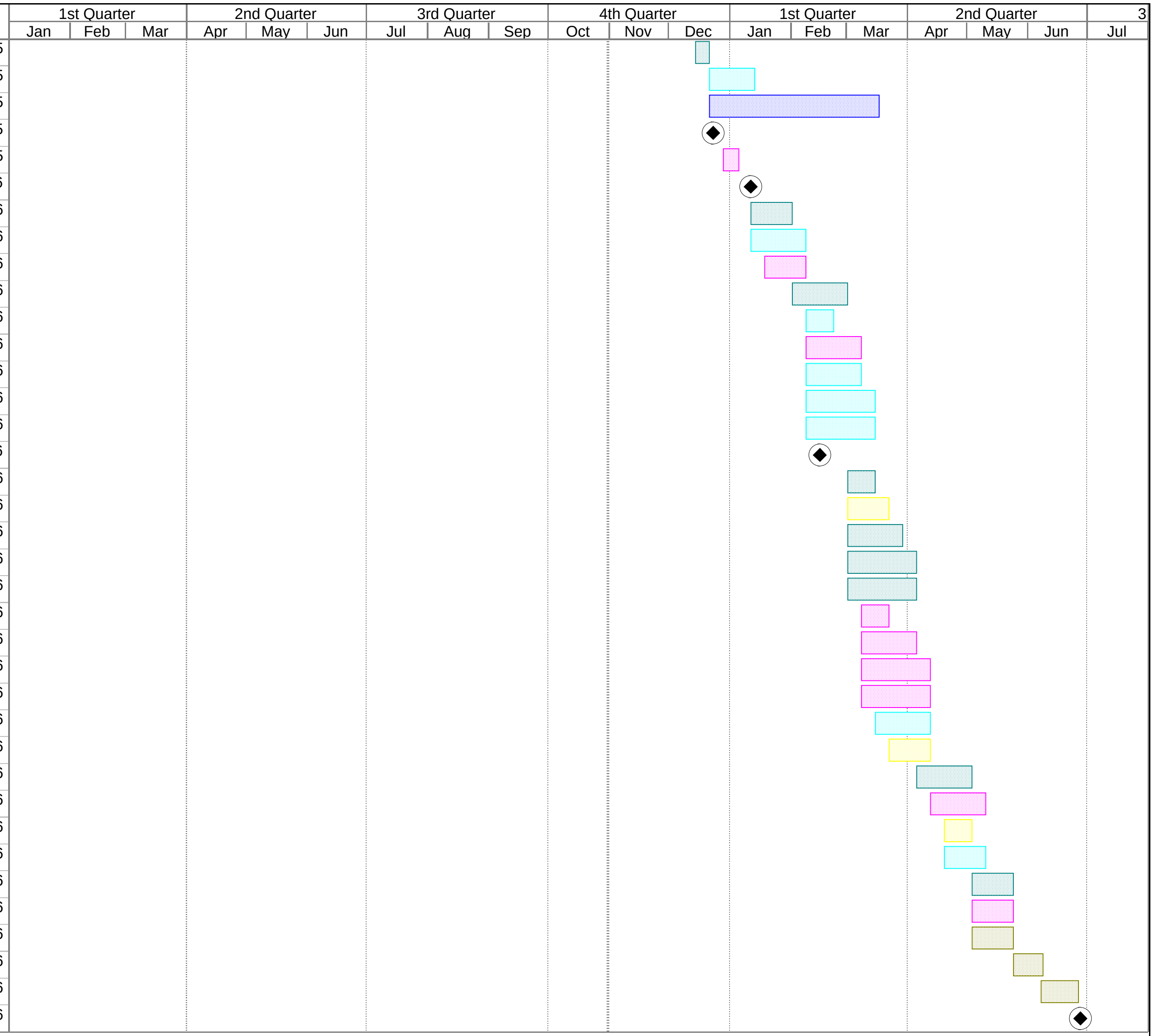
Task Name	Duration	Start
1st Floor Inrerior CMU Walls	20 days	Thu 9/8/05
Steel Erection Complete	1 day	Wed 9/14/05
Pour Final On Grade Section	5 days	Thu 9/15/05
Spray Fireproofing	15 days	Thu 9/15/05
Penthouse Framing	15 days	Thu 9/15/05
Rooftop Steel	15 days	Thu 9/15/05
Fire Pumps & Standpipe Installation	40 days	Thu 9/15/05
Mechanical Room 1st Floor Installation	58 days	Thu 9/15/05
Final Pour 2nd Floor Decking	5 days	Thu 9/22/05
Hoist Equipment To Roof	5 days	Thu 9/22/05
Permanent Utilities Tie-Ins	76 days	Thu 9/22/05
Final Pour 3rd Floor Decking	5 days	Thu 9/29/05
Glazing Panel Systems, East	30 days	Thu 9/29/05
First Floor Ductwork, Testing Insulation	45 days	Thu 9/29/05
Penthouse South Mechincal Installation	58 days	Thu 9/29/05
Penthouse EIFS	20 days	Thu 10/6/05
Penthouse North Mechanical Installation	53 days	Thu 10/6/05
Grand Stair Installation	60 days	Thu 10/6/05
Electrical System Configuration	96 days	Thu 10/6/05
1st Floor Framing	15 days	Thu 10/13/05
Masonry, Cast Stone Installation, North	20 days	Thu 10/13/05
1st Floor Sprinkler Lines	25 days	Thu 10/13/05
1st Floor MEP Lines	30 days	Thu 10/13/05
Second Floor Ductwork, Testing Insulation	45 days	Thu 10/20/05
1st Floor Bath & Kitchen Rough-Ins	20 days	Thu 10/27/05
Rooftop Equipment Installation	96 days	Thu 10/27/05
Seal West Wall	5 days	Thu 11/3/05
Louvers	10 days	Thu 11/3/05
Penthouse Roofs	15 days	Thu 11/3/05
2nd Floor Framing	15 days	Thu 11/3/05
2nd Floor Sprinkler Lines	25 days	Thu 11/3/05
2nd Floor MEP Lines	30 days	Thu 11/3/05
Third Floor Ductwork, Testing Insulation	45 days	Thu 11/3/05
Glazing Panel Systems, North	20 days	Thu 11/10/05
Roofing	30 days	Thu 11/10/05
3rd Floor Framing	15 days	Thu 11/17/05
2nd Floor Bath & Kitchen Rough-Ins	20 days	Thu 11/17/05
3rd Floor Sprinkler Lines	25 days	Thu 11/17/05
3rd Floor MEP Lines	30 days	Thu 11/17/05
1st Floor Fire Safing	5 days	Mon 11/28/05
3rd Floor Bath & Kitchen Rough-Ins	20 days	Thu 12/1/05



Project: Rockville Library
Date: Mon 10/31/05

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Task Name	Duration	Start
2nd Floor Fire Safing	5 days	Thu 12/15/05
1st Floor Sheetrock	15 days	Thu 12/22/05
Elevator Installation	60 days	Thu 12/22/05
Building Enclosure	1 day	Fri 12/23/05
3rd Floor Fire Safing	5 days	Thu 12/29/05
Site Permanently Powered	1 day	Wed 1/11/06
2nd Floor Sheetrock	15 days	Thu 1/12/06
1sr Floor Finishing	20 days	Thu 1/12/06
3rd Floor Sheetrock	15 days	Thu 1/19/06
2nd Floor Finishing	20 days	Thu 2/2/06
1st Floor Interior Glazing	10 days	Thu 2/9/06
3rd Floor Finishing	20 days	Thu 2/9/06
Doors, Hardware 1st Floor	20 days	Thu 2/9/06
1st Floor Millwork	25 days	Thu 2/9/06
Prime, Paint Walls 1st Floor	25 days	Thu 2/9/06
Building Climate Control	1 day	Wed 2/15/06
2nd Floor Interior Glazing	10 days	Thu 3/2/06
Grid, Ceiling Framing All Floors	15 days	Thu 3/2/06
Doors, Hardware 2nd Floor	20 days	Thu 3/2/06
2nd Floor Millwork	25 days	Thu 3/2/06
Prime, Paint Walls 2nd Floor	25 days	Thu 3/2/06
3rd Floor Interior Glazing	10 days	Thu 3/9/06
Doors, Hardware 3rd Floor	20 days	Thu 3/9/06
3rd Floor Millwork	25 days	Thu 3/9/06
Prime, Paint Walls 3rd Floor	25 days	Thu 3/9/06
Fixtures, Trimout 1st Floor	20 days	Thu 3/16/06
Lighting, Diffuser Installation	15 days	Thu 3/23/06
Fixtures, Trimout 2nd Floor	20 days	Thu 4/6/06
Fixtures, Trimout 3rd Floor	20 days	Thu 4/13/06
Ceiling Tiles	10 days	Thu 4/20/06
Flooring, 1st Level	15 days	Thu 4/20/06
Flooring, 2nd Level	15 days	Thu 5/4/06
Flooring, 3rd Level	15 days	Thu 5/4/06
Commisioning	15 days	Thu 5/4/06
Equipment Testing	10 days	Thu 5/25/06
Final Inspections	13 days	Thu 6/8/06
Project Completion/Turnover	1 day	Tue 6/27/06



Project: Rockville Library
Date: Mon 10/31/05

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Budget Analysis

The Rockville Library project is a very aesthetic and state of the art building design and those themes are reflected in the overall building budget. The areas of most significant cost: doors & windows, the mechanical, and finishes all reflect the principles of a quality and visually appealing construction project. The highest cost comes from the doors & windows section which reflects the cost of the exterior skin of the building. Since the entire perimeter of the building is encased with high quality glass paneling, it is obvious why the cost of doors & windows would be so high. In addition the serpentine curtainwall system is composed primarily of specialty acoustic glass, so the cost of this building system elevates the cost of the budget.

The mechanical system of the Rockville Library is state of the art and is budget to do so. The mechanical systems of the Rockville Library are designed to create spaces that are flexible, functional, energy efficient, and respond to the needs of the facility. This system will be controlled by an Automatic Temperature Control/Energy Management System, which will create the appropriate thermal environment for all building spaces.

Finally interior finishes are another significant project cost which reflects the interior aesthetics of the Rockville Library. This library was created to be a landmark project for the city of Rockville and its interior finishes are all of high quality and visually appealing.

Rockville Library Budget Breakdown

Base Bid Schedule Of Values:

Owner: Dept. Of Public Works | **Project:** Rockville Library

Proposal Date: 10/14/04 | **Total S.F. :** 102400 ft^2

Division	Description	Price by Division	Cost Per SF
Division 01:	General Requirements	$1,499,481	X
Division 02:	Site Construction	$256,433	X
Division 03:	Concrete	$1,001,957	$9.78
Division 04:	Masonry	$924,864	$9.03
Division 05:	Metals	$2,316,022	$22.62
Division 06:	Wood & Plastics	$523,734	$5.11
Division 07:	Thermal & Moisture Protection	$448,373	$4.38
Division 08:	Doors & Windows	$3,578,085	$34.94
Division 09:	Finishes	$2,056,658	$20.08
Division 10:	Specialties	$64,528	$0.63
Division 11:	Equipment	$26,471	$0.26
Division 12:	Furnishings	$78,387	$0.77
Division 13:	Special Construction	$0	X
Division 14:	Conveying Systems	$122,000	$1.19
Division 15:	Mechanical	$3,646,169	$35.60
Division 16:	Electrical	$1,953,856	$19.08
Sub-Total; Trades:		$18,497,018	$180.64
	Quality Control / Safety:	xxxxxxxx	
	Allowances:	xxxxxxxx	
	G.C. OH & Profit:	xxxxxxxx	
	Payment & Performance Bonds:	xxxxxxxx	
	Taxes / Other / Contingency:	xxxxxxxx	
Sub-Total; General Contract:		xxxxxxxx	
	Owner's Contingency:	$0	
	Design Team Fees:	$0	
	Builder's Risk Insurance:	xxxxxxxx	
Sub-Total; Owner / Other:		xxxxxxxx	
Total Bid Proposal:		$19,706,839	$192.45

Thesis Proposal #1

Investigation into Innovative Technology with Grahpisoft Constructor

Executive Summary

Innovative technologies, when used properly, can be a tremendous asset to a construction process by improving efficiency and coordination. These technologies range from 4D modeling, to collaborative project management software, to advanced accounting programs. All of these technologies aim at increasing organization by clearly defining the construction plan and how to implement it. Properly utilizing innovative technology is beneficial for improving the construction process without creating boundaries for implementation. Boundaries include excessive cost for implementation, proper training for using new technologies, and possession of the necessary equipment to implement technologies.

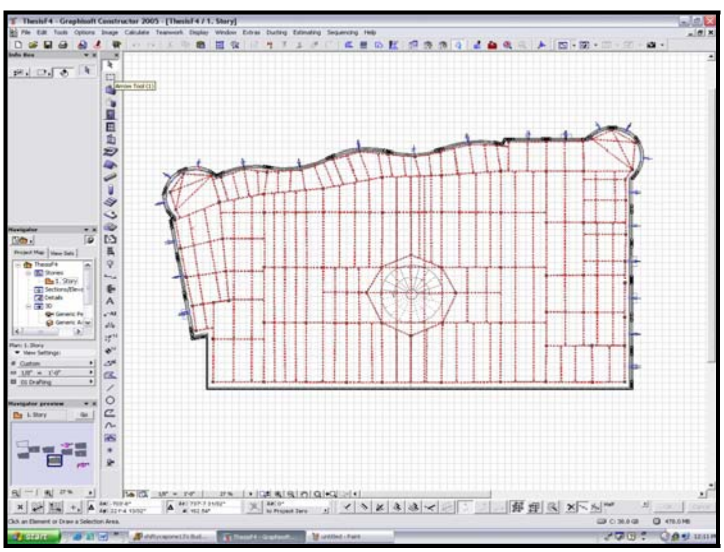
The Rockville Library project chose not to use any innovative technology in the construction process. The reasons given were that many of the subcontractors did not have the equipment or training to use most innovative technologies. Also, the general contractor for the Rockville project did not believe that innovative technology would significantly aid the construction process. However, during curtainwall erection, significant project delays occurred due to coordination issues and confusion about the serpentine design of the east building wall. Specifically, two weeks worth of delays occurred from coordination confusion and lack of organization in the serpentine curtainwall construction.

Using innovative technology during this phase of construction could have prevented these delays. Innovative technology such as 4D design could have planned out work flow, trade coordination, and design issues in the east curtainwall system. The purpose of this investigation is to identify a type of innovative technology that can meet the needs of the Rockville project without creating significant boundaries for implementation. This report will propose use of Graphisoft Constructor in order to create a 3D model of the curtainwall system, coordinate construction with a 4D model, and talk about including cost into the model to create an all inclusive innovative technology package.

Graphisoft Constructor

Graphisoft Constructor is an innovative technology that attempts to combine many different aspects of project management into one all inclusive program to organize the construction process. Graphisoft breaks construction down into five components: modeling, estimating, sequencing, procurement, and site management. By fully analyzing each of these components of construction, Graphisoft attempts to address all of the needs of a construction process into one efficient program.

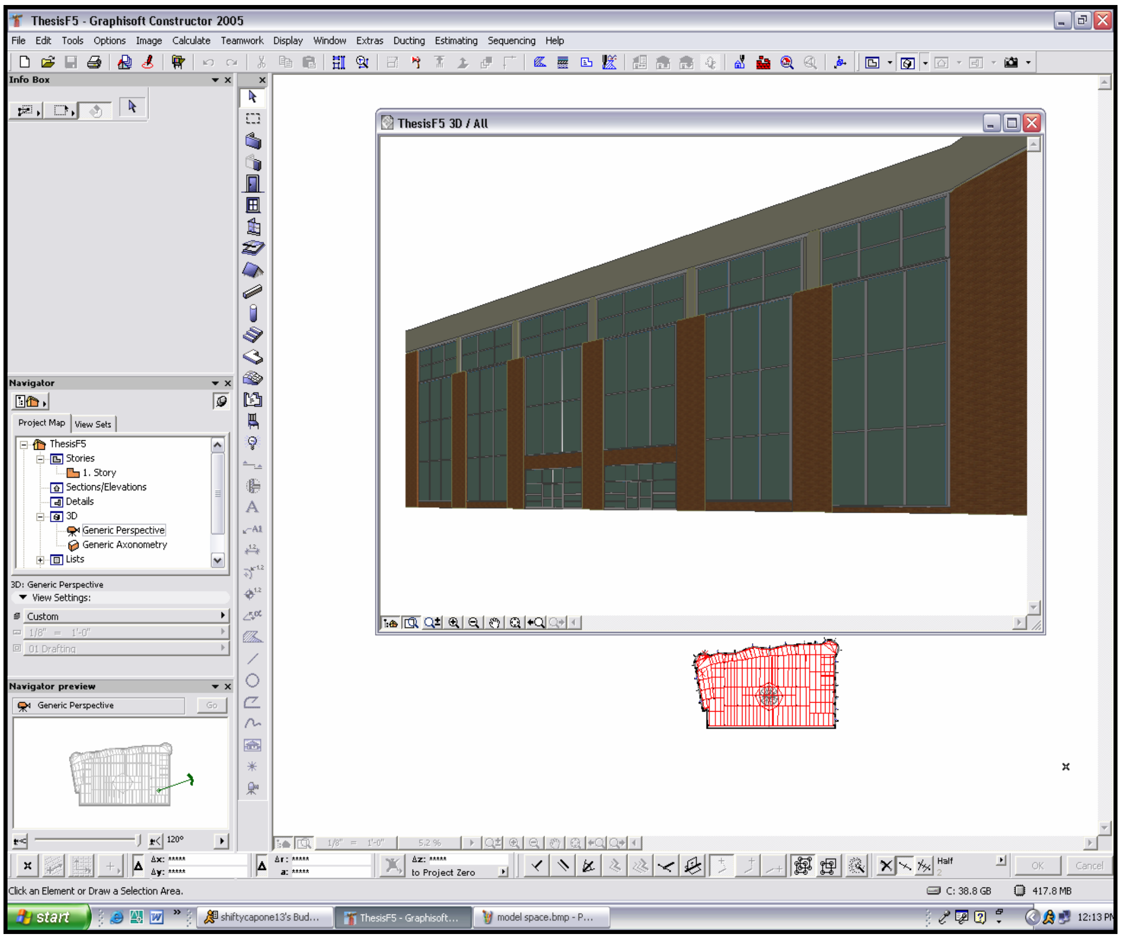
The first step to fully utilizing the Graphisoft program is to create the construction model. The construction model is the foundation of the constructability analysis, provides building component locations, and addresses zoning concerns. Constructor, unlike programs like AutoCAD and VIZ, is solely geared toward building construction so all of its modeling functions are construction oriented. Instead of drawings lines or regions that later need to be identified as materials or building components, Constructor has settings for creating walls, beams, roofs, and any other building component that the program instantly identifies as a building component rather than a shape. Once a building element has been created, it can be modified to be identical to a real component in the construction project.



Example of Model Space in Constructor

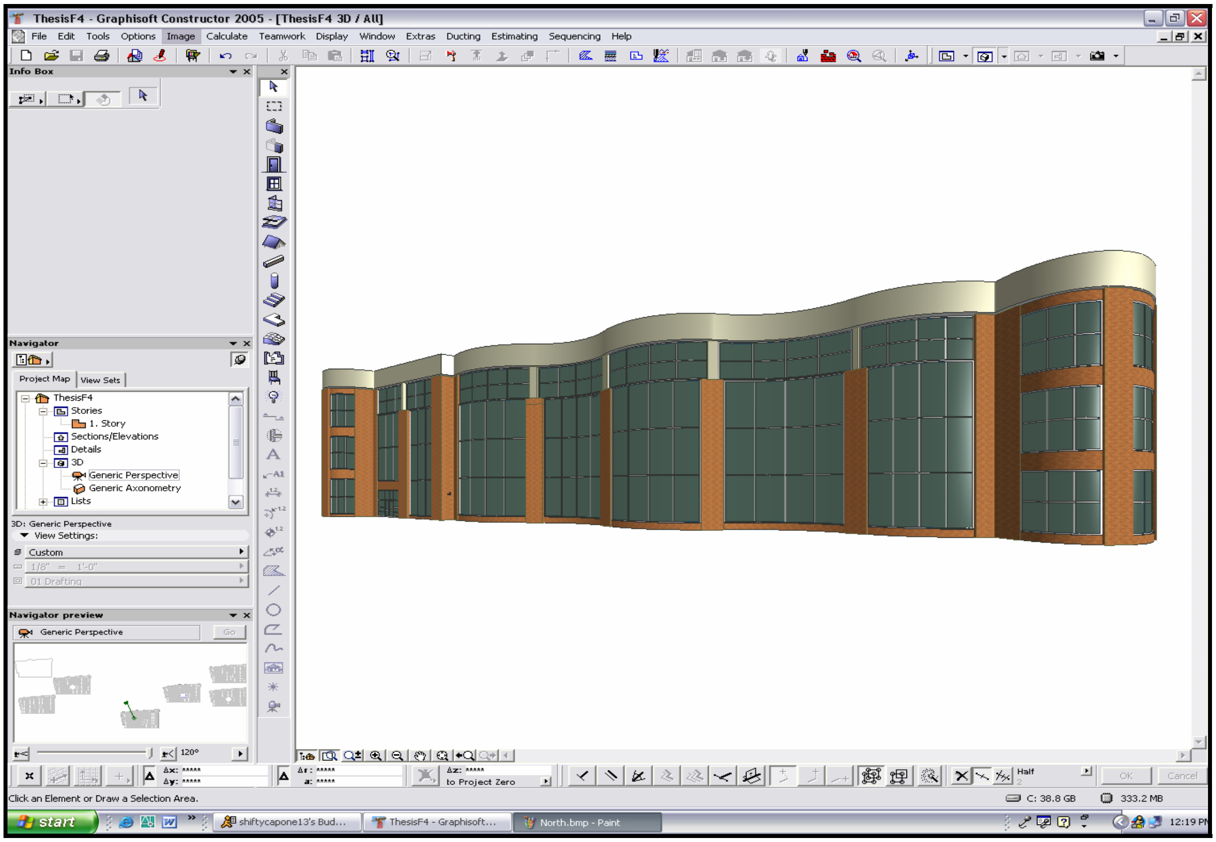
For any object the shape, size, materials, connections, and constructability can be identified and adapted toward a projects true design. As the level of detail in the model increases, the more it gets close to the real thing. Since Constructor already recognizes model elements for being real construction elements, eventually the elements in the program will become as real as something built in the field.

Once elements have been constructed in model space they can be instantly viewed and modified in 3D perspective.

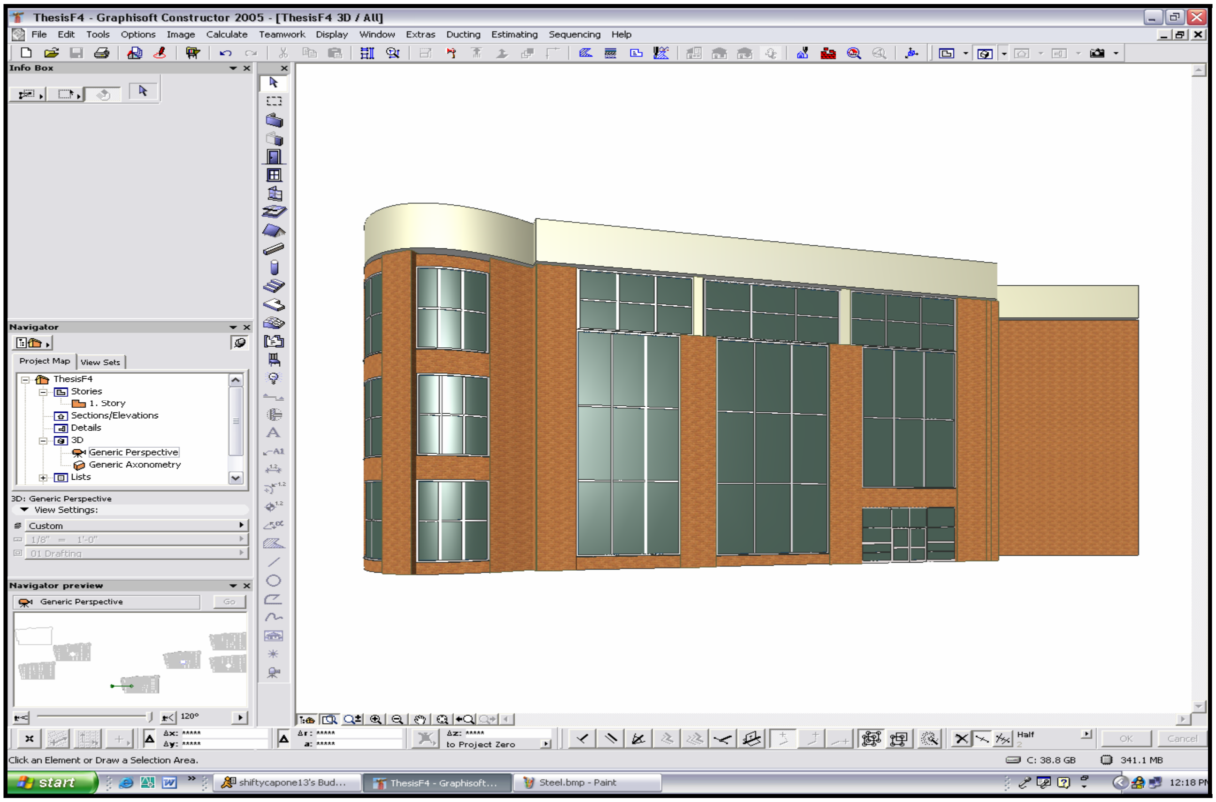


Example of South 3D Perspective

The 3D perspective gives a detailed look at how the elements will look once constructed in the field to the specifications given. Perspectives work as a camera that can wrap around and focus towards any part of the building design. Above is the south elevation of the Rockville Library in Constructor, below are the East and North perspectives.

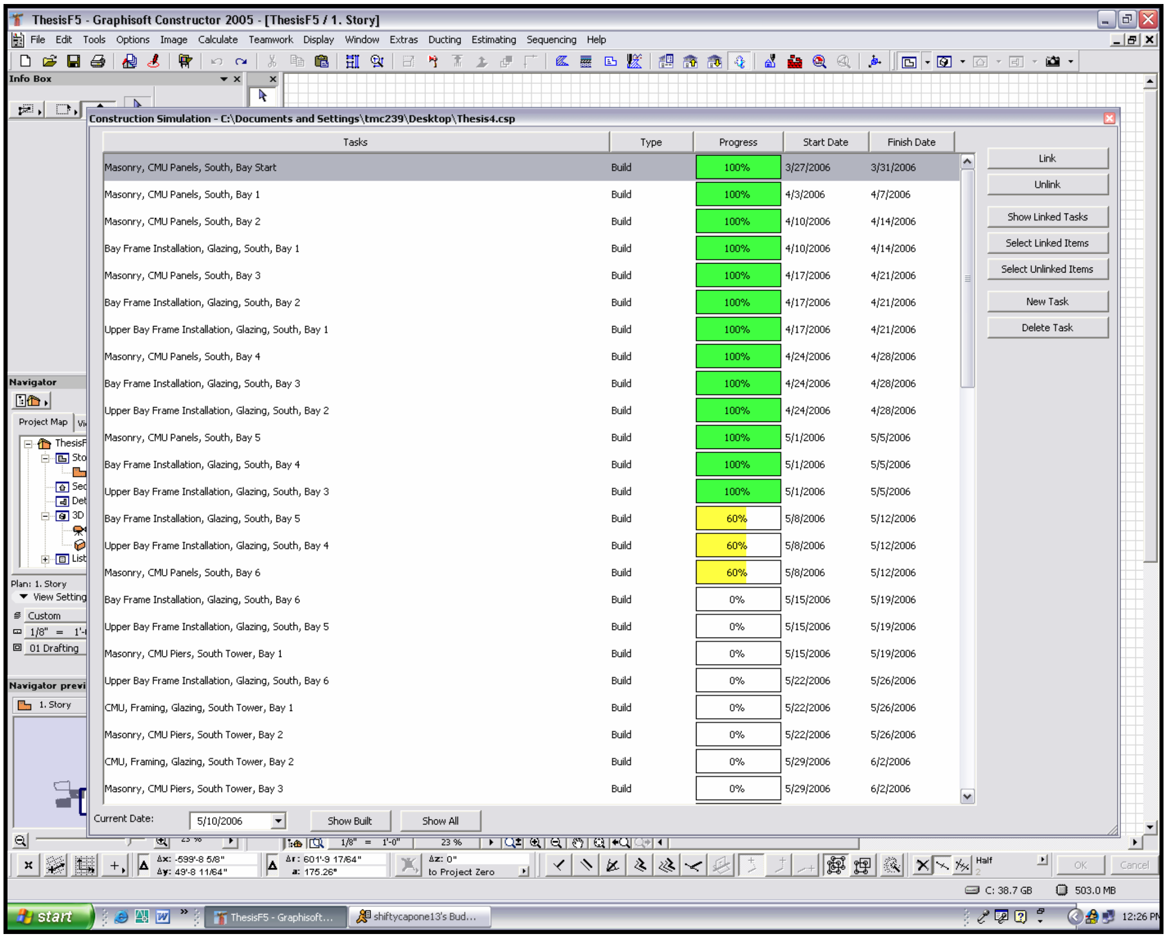


Example of East 3D Perspective in Constructor



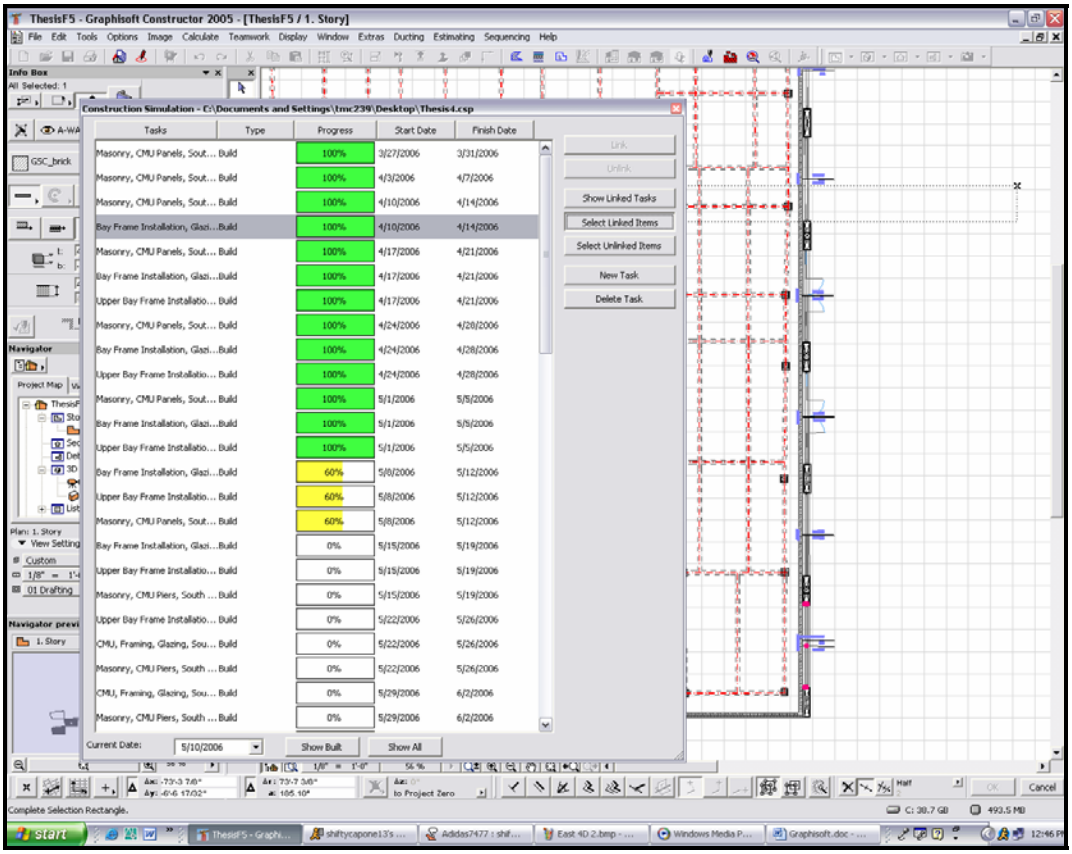
Example of North 3D Perspective

Once modeling is complete for desired building elements, they can be quickly translated into 4D models using the construction simulation program in Constructor. In order to use the construction simulator the building schedule must be inserted into the Constructor program. Programs like Microsoft Project can be formatted into Graphisoft or the schedule can be inputted directly into Constructor. Once a task has been entered a start and completion date must be identified. Constructor will automatically input the task into the schedule and show its percent completion based on the current date of the project.



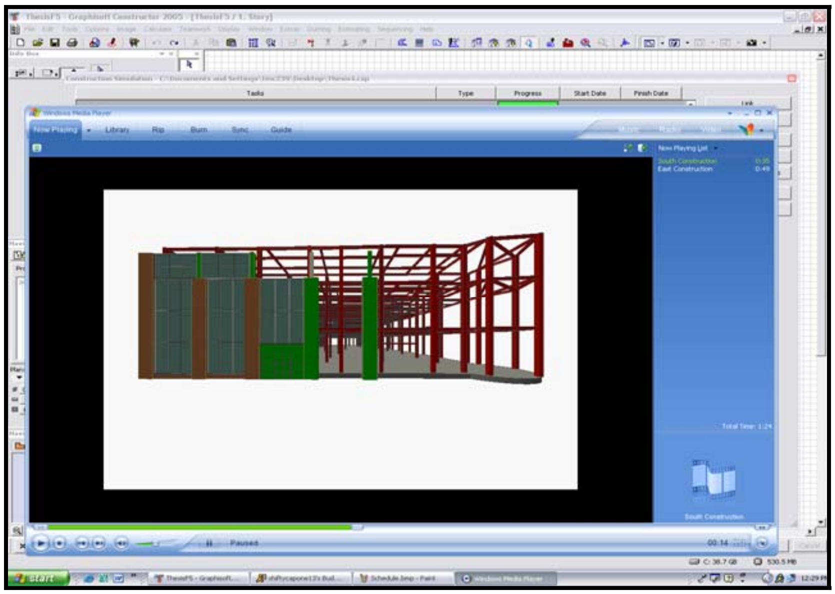
Example of Schedule Linking in Construction Simulation Program

Once the schedule is inputted into Constructor, building elements can be linked to the schedule in order to integrate the model to the building schedule. Objects can be individually linked and modified with ease in the construction simulation program. Objects that have been linked to a task in the construction schedule can be viewed by displaying the select linked items menu in the construction simulation. This feature makes organizing the model into the schedule easier since there is a way to keep track of each of the building elements.

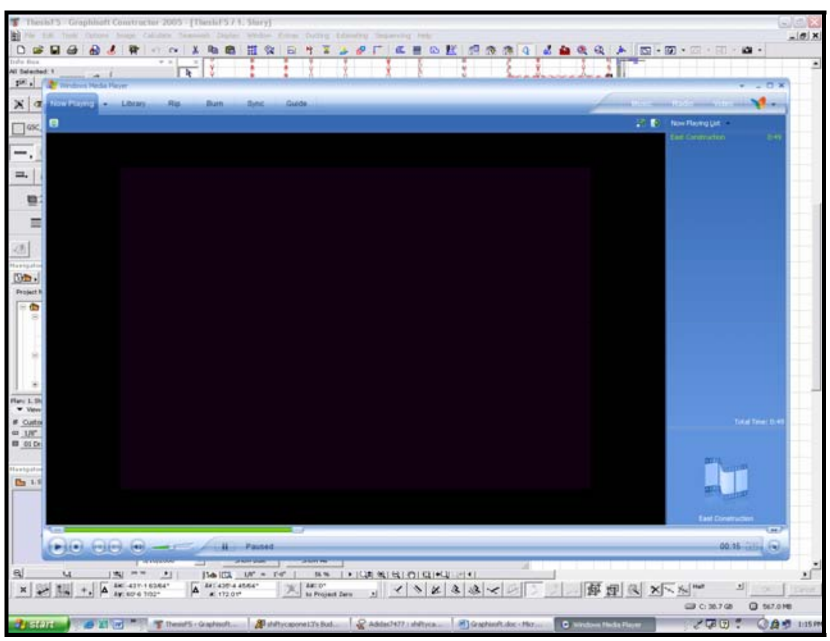


Example of Linked Building Components in the Schedule

Once all building elements are properly linked to the schedule, construction animation can begin. Construction animation erects the building on camera in the manner identified in the project schedule. The animation can begin at any date in the construction process and from any view in order to get a full 4D perspective. These animations can be converted into a Quicktime movie file or Windows Media Player avi file in the animations settings. Combining the different elements of the 4D views and construction dates can create a full interactive 4D model. The 4D model created with the Rockville Library project was the sequencing of work in the south and east building envelope erection. Tasks were sequenced according to the plan in the Rockville Library schedule and translated to the Constructor program. The 4D model is intended to show how tasks are sequenced in erecting building envelope components, especially the serpentine curtainwall. Unfortunately, Constructor does not include construction equipment like cranes and concrete pumps that can be integrated into the construction simulation. Captioning can be included in any 4D model to compensate.



Scene of South 4D Sequencing



Scene of East 4D sequencing (Errors with displaying video in paint may cause difficulty viewing picture).

Conclusion

Graphisoft Constructor is an effective tool for creating 3D and 4D modeling that can be used to facilitate the Rockville construction process. By implementing this 4D technology, the time lost in coordination, especially in the eastern serpentine curtainwall, can be saved and costs reductions can be produced. Innovative technology like this may have a learning curve and take time to be implemented on a project. However the time and money lost in project delays frequently exceeds the cost in implementing innovative technology. With the complex features and the extremely limited site of the Rockville Library, miscommunication can easily occur and cost the project significant amount of money. It is recommended by this investigation that projects that have complex features, like a serpentine curtainwall, or have little room for coordination error, like the Rockville Library site, utilize innovative technology to make sure the construction process goes smoothly.

Graphisoft Constructor is a good program to implement 4D technology in some aspects, but is lacking in many others. Graphisoft creates very high detailed models that can be adapted and viewed regularly to manage the changing conditions on site. 4D modeling can also be preformed easier than in programs like CAD and VIZ since a building schedule can be directly attached to building elements in the model. Construction animation is also very flexible and clearly shows the sequencing of work in all aspects of a project. Animations can easily be transferred and shown to any subcontractor on site so the boundary for displaying this technology is low. All that is needed to show construction videos is a computer with a media player.

While there are many benefits to a program like Constructor with its high level of detail and adaptability, there are also major downfalls. The learning curve for using this software is very high. It takes a significant amount of time to learn how to use its modeling tools since they are so detailed and sensitive to change. Constructor is also unlike any of the CAD or VIZ programs so a whole new language of software and tools need to be learned in order to construct a basic 3D model.

In addition Constructor utilizes a very complex recipe system. In the recipe system, script needs to be written for each object created in model space. The script includes parameters, 3D modeling, 2D modeling, and master script components. The script must be written in a code that Constructor can understand. Scripting codes allow for very high detail building components, however Constructor never effectively explains how the code should be constructed or displayed. Constructor in general has a very poor help section which ends up leaving more questions than answers. This makes a contractor dependant on Graphisoft to receive training and answers on how to utilize their programs constantly.

In addition, without creating script for every building component, cost estimating cannot be integrated into Constructor application. Simply by designing a building in model space is not sufficient. Script must be created for each object and matching script in Graphisoft Estimator allows cost to be tied to the project. Without proper understanding of the script and computer language, the full potential of the software cannot be reached. Even after the Rockville model was completed, as shown, cost could not be tied into it without remaking the entire building out of script. Constructor help and online conversation did not meet the needs for me to understand the GDL script concepts. Personal training is recommended in order to use this program fully. Without it only so much can be accomplished.

Moreover, project files in Constructor become very large as the model develops. Often it will take over five minutes for a model to load, making it very difficult to display plans. Constructor also was very difficult to run on any computer. A computer needs to develop a network connection to Graphisoft's tutorial in order to run outside of demo mode. On my personal computer I was not able to accomplish a network connection due to limitations on my laptop. Very frequently Constructor crashed when trying to load 3D perspectives in the AE computer labs. It is recommended that a very advanced computer network be set up for properly utilizing Graphisoft programs.

Overall Graphisoft Constructor is one of the most detailed and in-depth programs for design I have ever used. However, the overwhelming boundaries for properly utilizing

Constructor do not make this program recommended for use. A program like Constructor takes months of training and personal consultation from Graphisoft in order to use properly. If the time and the network capabilities are present then Constructor can be a great asset. Otherwise it will often lead to very frustrating and confusing situations.

Thesis Proposal #2

Value Engineering Analysis of The Serpentine Curtainwall System

Executive Summary

During the preconstruction stage of any project, there is a period when the building design needs to be analyzed for possible value engineering ideas. Developing value engineering ideas can often lead to lower costs, accelerated schedules, or environmental benefits. In the case of the Rockville Library project, value engineering was often aimed at driving down project costs. Montgomery County had already spent a significant amount of money on the project to ensure that it was highly aesthetic and state-of-the-art. It then needed to find ways to drive down the cost in other areas of the project without sacrificing either of those aspects.

One value engineering idea that was proposed involved the serpentine curtainwall system. Originally the design for the project was to have a structural (tube) steel support system for a shallow depth (4 1/2") curtainwall system. The value engineering suggestion was to eliminate the tube steel support system and instead use a self-supporting, 12" depth curtainwall system. The basis behind this value engineering proposal was that by loosing the steel material costs from the curtainwall, costs could be reduced in the curtainwall erection process. However, it is not entirely clear if cutting these material costs in favor of a larger curtainwall system was actually the correct value engineering decision.

The purpose of this investigation is to analyze the difference between the 4 ½" and 12" curtainwall systems and identify which one is more beneficial to the construction process. Factors such as material costs, the equipment needed, schedule impacts, and

structural limitations will all be evaluated in order to find out which system is the best fit for the Rockville site. The goal of this investigation will be to find areas in the structural system of the serpentine curtainwall where costs could be reduced, particularly questioning if they are best reduced in the originally designed system or in a middle ground between the old and the new.

Curtainwall View from East Elevation

Curtainwall Background

The Rockville Library curtainwall system was designed by Galaxy Glass & Aluminum Inc. out of Manchester, New Hampshire. Galaxy's responsibility was to pre-fabricate and deliver as much of the curtainwall system as possible. The serpentine curtainwall is broken into concave and convex bays that could only be pre-fabricated individually and delivered to the site. The ladder bays are made out of aluminum and are fully assembled to meet the specifications of the building drawings. In the field the ladder bays are connected with a shear block connection. The aluminum blocks are screwed into vertical mullions which are fastened horizontally. All glazing involving the curtainwall system is to be done in the field as well.

Current Photos of Curtainwall Erection.

Galaxy specified that the original curtainwall system was thinner and structurally supported by structural steel tubing. The type of steel tubing used to support the 4 ½” system was TS 12” x 4” x 3/8”, TS 14” x 6” x 3/8”, and TS 12” x 4” x ¼” steel tube.. According to the Rockville staff, this steel was being priced at a rate of $2500 –

$2800 per ton. Value engineering stated that by eliminating the steel material costs would be lowered.

The alternative to a steel supported curtainwall is a thicker curtainwall that could self-support any vertical building load. There are structural limitations on the curtainwall system and in order to have no structural steel backing it was determined that a curtainwall thickness of 12" should be used. According to Galaxy, a multiple bay curtainwall that spans from slab to ceiling, with bays less than 25', can support a typical building load at widths of 10 ½" to 12". Anything less than 10 ½" would need intermediate anchors in order to stabilize the curtainwall. To be conservative the Rockville construction team went with the 12" curtainwall system.

Curtainwall Takeoff

In order to analyze which system would have been more effective to implement, it is necessary to perform a takeoff and cost analysis of each curtainwall system. Takeoffs will be preformed from the Rockville building drawings which include plans for both the 12" and 4 ½" curtainwall systems. The square footage of curtainwall will be measured using a scale, and the building drawings and steel members will be cataloged using the same procedure. Once all of the steel members of the 4 ½" curtainwall system are recorded it will be necessary to find their corresponding weight in the ASCI steel manual. Once weight per square foot numbers have been found for each steel member, steel tonnage must be calculated in order to find the price of the steel package in the

curtainwall system. Steel prices were obtained through Forrester construction and curtainwall prices were obtained through Bovis Lend Lease's cost database.

Curtainwall Takeoff

Segment	**Linear Feet**	**Height**
Bay 1	17'	58'
Bay 2	17'-3"	58'
Bay 3	17'	58'
Bay 4	18'	58'
Bay 5	17'-6"	58'
Bay 6	17'-6"	58'
Bay 7	17'	58'
Bay 8	17'-9"	58'
Bay 9	18'	58'
Bay 10	14'	58'
Bay 11	7'	58'

Total Curtainwall Length - 178'
Curtainwall Height - 58'
Curtainwall Area - 10324 ft^2

4 1/2" Curtainwall Steel Takeoff

Member	**No. of Members**	**Member Weight (lbs/ft)**	**LF of Steel**	**Tonnage**
TS 12" x 4" x 3/8"	29	37.6	493	18.54
TS 14" x 6" x 3/8"	21	25.8	356	13.16
TS 12" x 4" x 1/4"	30	84.1	510	29.94

Total Tonnage- 61.64 tons
10% waste factor 6.164 tons
Final Tonnage- 67.8 tons

4 1/2" Curtainwall System

Steel Members - 67.8 tons
Steel Cost - $3500 per ton
Curtainwall Area - 10324 ft^2
Curtainwall Cost - $50/sf

Total Cost - $753,500

12" Curtainwall System

Curtainwall Area - 10324 ft^2
Curtainwall Cost - $90 per sf

Total Cost - $929,160

Resulting Savings - $175,660

Conclusion

From the preformed cost analysis and takeoffs it seems clear that the 4 ½” curtainwall system would be preferred over a 12” curtainwall system. Even with escalating steel prices and fabrication costs there are still over $ 175,000 worth of savings in selecting a thinner curtainwall system. Then the question that needs to be asked is: why was the system changed in the first place?

According to Forrester Construction, structural steel is currently priced at $2,500 to $2,800 per ton, fabricated and installed. There is, however, a complexity factor associated with erecting steel for the 4 ½" curtainwall system that makes it less like structural steel work and more like miscellaneous metals work. Therefore, the price to provide this work could end up being upwards of $3,500 per ton. To be conservative, the cost of the steel work in the curtainwall system would be approximately $ 237,300. Cutting this cost would save a significant amount of money, however, there would need to be compensation in structural support by installing a thicker curtainwall system. If the value engineering department solely looked at losing the steel cost without understanding the cost increase of installing a thicker curtainwall, then the mistake could be understood.

However, other factors that make a thinner curtainwall more beneficial make the argument for a thicker curtainwall even more unreasonable. A thinner curtainwall system would take less time to fabricate and would be cheaper to deliver to site due to its lower weight and less material. In addition steel construction is considered to be much simpler than curtainwall construction due to the complexity of the serpentine panels. A thinner system would be more constructible simply because of its lighter weight and smaller size versus a thicker system. A thicker system would have the benefits of more sound insulation and being a better thermal barrier than a 4 ½" system, however the pros of a thinner curtainwall with steel supports still outweigh the benefits of a 12" system, especially when cost is considered.

According to Bovis Lend Lease, the cost per square foot of installing and furnishing the two curtainwall systems were at $50/sf and between $90-$100/sf. These costs per square foot were taken from the Princeton office of Bovis and since there was not much difference in location factors or cost of construction between the southern New Jersey area and the greater Maryland area, costs for furnishing and installing the two curtainwalls should be similar. After takeoffs were preformed on the curtainwall drawings there was a significant cost difference between the two systems, so much of a difference that the structural steel supports did not exceed the additional costs for a thicker curtainwall system.

Overall, each system would be considered sufficient to support the needs of the Rockville Library. They provide natural sunlight to the library, create an aesthetic environment, and provide adequate thermal and noise barriers. The major difference between the two systems is cost. With over $ 175,000 in savings, there is no reason not to consider the 4 ½” system the more economical of the two curtainwall systems. That is why this investigation is recommending use of the 4 ½” curtainwall system with steel support over a 12” substitute.

Thesis Proposal #3

Principles of Design for Disassembly & Its Impact on the Rockville Library

Executive Summary

The Rockville Library is a site that has a significant social and cultural impact on the city of Rockville, Maryland. The library is designed to be the centerpiece of the new town center project along with a major resource for the community. With its symbolic serpentine curtainwall façade, glamorous interior design, and state-of-the-art researching tools, it can be seen how the Rockville Library is an important building that will be used by the community for many years to come.

With that said it is very important for this building to be prepared for future additions, renovations, demolitions, and repairs as the components and functions of the library changes. Libraries are frequently under some form of construction due to the constant change in technology and the way that we research data. Within the past 20 years it has become essential that every library have a computer lab and the capability to power a telecommunications network. Instead of space for bookshelves and card catalogs, library designers are concerned with making the library space suitable for computer use and wireless Internet. This change in the way that we research has led to the renovation or rebuilding of every library in the country in order to make them up to date with the needs of the community. In the future who knows what our needs may be when it comes to research, thus libraries need to be flexible and prepared to adapt to change.

The old Rockville Library fell under the category of a building that needed to be rebuilt in order to fit the new needs of the community. The library was moved across the city into the new town center and redesigned completely. The new facility is over 100,000 square feet and cost over 25 million dollars to construct. In addition it is located to be a highly visible symbol for the city that can be accessed either by car or Metro. After the county of Montgomery has selected such a great site and put millions into designing and constructing this library, it is not likely that they will want to go through another process of completely demolishing and reconstructing the library elsewhere again. So it is important to realize that this library needs to be prepared for renovation as the times change.

This investigation will specifically look at the process of deconstruction, more specifically the purpose of designing for disassembly. Deconstruction is the selective dismantling or removal of materials from buildings prior to or instead of conventional demolition. Deconstruction is an alternative method of building demolition that can offer economic and environmental benefits. One branch of deconstruction is the process of design for disassembly.

Designing for disassembly is planning for deconstruction in the future. It is the method of ensuring that in the future when parts of the building need to be removed, replaced, or renovated that the maximum economic and environmental savings can be achieved. This investigation will look into the process of design for disassembly and how it can be applied to the Rockville Library construction process, specifically the structural connections. The goal of this investigation is to create environmental or economic savings in the Rockville Library construction process by applying the ideas of design for disassembly.

DFD Process

DFD (Design for Disassembly) planning occurs during the design phase of the construction process and takes into consideration all of a building's components and how they are to be handled in future deconstruction. Preparing a building for future deconstruction, whether it is partial or complete, would save considerable time and money for a building owner. In addition any contractor would save considerable time and resources in demolition or renovation since DFD plans would already show how to disassemble and salvage any component of the building. DFD is a form of building design that is extremely efficient and can help save future cost on any construction project. However, in order to create a DFD plan in the design phase it takes additional resources at the beginning of a project.

Adequate time in the design phase of the construction process needs to be given in order to make sure that DFD is investigated into each building component. The amount of time that should be dedicated to developing a proper design for disassembly scheme depends on the size and scope of the project. A building with limited site space or a high number of components needs the necessary planning time in order to ensure the success of the deconstruction process.

In addition to adequate time, it may also be necessary to hire a subcontractor that will oversee the design for disassembly process. There are companies both foreign and domestic that have expertise in the design for disassembly process and can be hired in a cost plus fee contract similar to an architect. Having an entity in charge of defining this process at the onset of the design phase can make things go a lot more smoothly than trying to create a design for disassembly plan out of existing conditions. Depending on how complicated the process will be or how rigorous of a deconstruction plan is desired will make the decision of whether or not to hire a separate entity in charge of disassembly. Overall, it is important that the design staff has an understanding of the principles of DFD and is properly prepared to handle the process. If a construction team feels that it can adequately plan for deconstruction on its own by following the guidelines of DFD, than a separate specialty group may not be necessary at all.

Once the proper staff is in place for designing with DFD in mind and given the proper time to plan the process with an in-depth look into DFD; the design process should begin. In order to create a building design that caters to future deconstruction, then it is important that the principles of DFD are followed.

Principles for DFD

1. Use recycled and recyclable materials
2. Minimize the number of types of materials
3. Avoid toxic and hazardous materials
4. Avoid composite materials, and make inseparable products from the same material
5. Avoid secondary finishes to materials
6. Provide standard and permanent identification of materials

7. Minimize the number of different of different types of components
8. Use mechanical rather than chemical connections
9. Use an open building system with interchangeable parts
10. Use modular design
11. Use assembly technologies compatible with standard building practice.
12. Separate structure from the cladding.
13. Provide access to all building components.
14. Design components sized to suit handling at all stages.
15. Provide for handling components during assembly and disassembly.
16. Provide adequate tolerance to allow for disassembly.
17. Minimize number of fasteners and connectors
18. Minimize number of connectors.
19. Design joints and connectors to withstand repeated assembly and disassembly
20. Allow for parallel assembly
21. Provide permanent identification for each component
22. Use a standard structural grid
23. Use prefabricated subassemblies
24. Use lightweight materials and components
25. Identify points of disassembly permanently
26. Provide spare parts and storage for them
27. Retain information on the building and its assembly process

The main principles of design for disassembly focus on building materials, building components, and recording information. By planning disassembly around all three of these areas, future deconstruction can be preformed efficiently with minimal impact to the current site.

Materials used in the building are very important to consider because eventually they will have to be either reused or removed from the site. By only using materials that can either be reused or recycled ensures that during deconstruction, all building components will have a function after they are disassembled. Reusing materials on site would be ideal; however being able to recycle any additional materials would give a profitable and environmentally friendly way to remove the building materials from site. Using fewer materials, none that are hazardous, and avoiding secondary finishes all make the process of handling materials after deconstruction easier and safer.

The use of modular design is also a major theme of DFD. Modular design is creating building components that are standardized and easy to assembly and disassemble without interfering with other building components. Modular design makes it easy for disassembly to occur since a piece of the building can be easily identified and renovated without having to damage any other building system. Not damaging any current building system or having to do any unnecessary demolition is one of the main goals of DFD. This can be accomplished by making sure all building components are openly accessible for any kind of repair or renovation and that connections holding a building component in place are minimal and removable so that the impact of deconstruction is minimal to surrounding building components.

Finally, keeping a detailed account of how the building is designed for disassembly and how future deconstruction can occur efficiently is important in order to save cost in future projects. DFD is a design principle that creates its savings in future construction work. By designing for disassembly a plan can be created to reuse and remove all building materials and components from site with minimal impact to its surroundings. The only way that this can be ensured is by keeping a strict building inventory, marketing salvageable materials, and preparing equipment and safety plans for future deconstruction. Keeping a detailed log of how each piece of the building is intended to be disassembled and handled is the only way that future deconstruction can gain the full benefits of DFD.

The benefits of DFD may not be very visible in the present, but will be very apparent in the future. Planning for deconstruction in advance will help the owner save considerable money in renovation and demolition costs. In addition proper building deconstruction will result in lower building removal costs because of the value of salvaged materials and avoiding disposal costs. Also, well-planned DFD will reduce future impact to the site including less dust and noise than conventional demolition. Finally, DFD helps the environment by conserving landfill space by diverting up to 90% of a building into reuse and recycling, and protects the environment by reducing the need for extracting new resources.

The Rockville Library & DFD

The current design for the Rockville Library is an excellent candidate for DFD for many reasons. Not only because of its significant impact in the community, but because of Rockville's congested site, its building materials, and structural assembly.

Rockville's congested site would make it very difficult for conventional demolition or renovation to occur. The small site space and shared west wall with a neighboring building makes construction at this site very difficult. In the future as the town center continues to expand and crowd performing construction in this area will become even more difficult. DFD is the solution to this problem since designing for disassembly will ensure that minimal impact to the site will occur.

Rockville Library is also constructed with high-value specialty materials such as architectural molding, unique doors and windows, and unique electrical fixtures. These materials can retain much of their value if they are designed to be properly removed and salvaged. DFD can accomplish this by planning how the unique features of the Rockville Library can be disassembled and handled in future renovations.

In addition, the structural system of the Rockville Library is a good candidate for DFD because of the simple connections and open spaces to allow for stripping of salvageable materials. The Rockville Library is designed with lighter steel supports, thinner concrete slabs, and simple connections due to the relatively low load requirements demanded. Open spaces in the structural system are present in the lobby and open reading rooms of the library. These factors in the structural system make sure that deconstruction can be achieved without impacting the site heavily.

Guideline for DFD in Building Connections

Typically a curtainwall renovation project is preformed to improve the performance parameters of the system which may include aesthetic, structural, thermal, or weatherproofing features. A renovation project normally requires a complete stop of building interior operations. This is because the scope of the work requires the removal of the existing curtainwall panels and supports. New supports and panels need to replace them , producing building holes during construction. Building holes create a problem of protecting the building against weather and thermal loss so the building often needs to be shut down. In most cases, the interior wall and many interior fixtures are attached to the existing curtain wall supports. Therefore, replacing the existing curtain wall supports would require massive restoration of interior wall and fixtures. In most cases, the cost of renovation often outweighs problems with the curtainwall structure. Even if money and building holes are not a factor, heavy construction that results from having to disconnect and reconnect curtainwall panels make building operations not possible.

Currently the Rockville Library project utilizes stud welding in order to fasten curtainwall assemblies to the structural framing. Stud welding is a highly rapid and efficient way of attaching curtainwall units. The process consists of arc-welding studs to the metal structural frame, creating a permanent bond between the curtainwall assemblies and its frame. Although welding is an effective way to weatherproof and efficiently bond curtainwall components, it does not take into consideration future disassembly. Connections like these are one of the main reasons that curtainwall renovation is such a long and laborious process.

Instead of welding connections, using metal inserts would be a much more effective from a disassembly standpoint. Unistrut-type metal inserts utilize continuous slotted inserts with anchor legs and special springnuts and bolts. These metal inserts eliminate the need for welding and gives a flexible connection that provides unlimited adjustment along the face of the building. This connection would allow for much easier renovation and maintenance while still providing the same strength and constructability as welded connections. While there is a cost increase addressed below, the overall cost increase of implementing this system can pay for itself in lower future renovation costs.

Connection Pricing

Type Of Connection	Size	Units	Material Cost	Labor Cost	Equipment Cost	Total Cost
Unistrut Metal Fastener	1-1/4" Diameter, 4" Long	Each	$1.74	$4.00	X	$5.73
Arc Welding	1/2" Diameter, 4-1/8" Long	Each	$0.39	$0.65	$0.26	$1.30

Estimated # of Curtainwall Connections – 1800
Total Cost of Arc Welding System - $2,340.00
Total Cost of Unistrut Metal Fasteners – $10,314.00
Estimated Cost Increase – $7,974.00

Conclusion

Design for disassembly is very important to consider in any construction process. In terms of the life-cycle of a building, only two percent of a building's total cost is in its construction and the remaining 98% is from operations and maintenance costs. Applying any of the principles of design can help reduce future costs tenfold over traditional building planning.

Owners are usually only concerned with bottom-line construction costs, but designing for disassembly can save a building owner more in the long run. Although taking time in the design stages to plan a deconstruction plan may cost time and money in the preconstruction stage of a building's life-cycle, in the end it will make up for its costs. By investing more money into recyclable materials or connections designed for deconstruction, like some metal inserts, significant costs can be saved in renovation that may even eclipse the initial cost of implementing these systems.

The moral of design for disassembly is that a building can begin to prepare for its deconstruction even before it is built. Following the principles of design for disassembly, even in the smallest ways, can help keep down renovation costs in the long run. In the case of the Rockville Library, design for disassembly can definitely benefit and help reduce costs for the reasons mentioned above. Connections in the curtainwall are just one small example of this. Even though there may be higher cost in building construction related to design for disassembly measures, the intention is to lower the cost of the system over its entire life-span. Currently there may be a price increase for implementing bolted connections that allow for easier maintenance and disassembly. Yet, in the future the costs for removing welded connections in renovation, the loss of money from closing the building during renovation, and the cost of repeating the welding process again for each renovated connection would cost significantly more than the initial cost increase from an adjustable metal fastening system. With these fasteners maintenance and renovation is much less intrusive to the building system and is much less laborious.

These kinds of examples are what design for disassembly stands for. Creating future savings in renovation, maintenance, and recycling while making as little of an initial cost increase as possible is what DFD stands for. While the curtainwall connections were just one step in the overall process, there are many more measures that can be taken. By going through a building's design and applying the principles for DFD, significant savings can be made. Every step taken towards design for disassembly is another step in improving the future life-cycle of a building and aiding operating cost.

Thesis Proposal #4

Alternate HVAC Ductwork System with DuctSox Fabric Technology

Executive Summary

The mechanical system of the Rockville Library is designed to create spaces that are flexible, functional, energy efficient, and respond to the needs of the facility. The HVAC system is controlled by an Automatic Temperature Control/Energy Management System, which creates an appropriate thermal environment for all building spaces. The system consists of three different types of distribution methods selected to accommodate the size and desired noise levels of each building space. In the stack area, a constant volume terminal reheating system is utilized while in the office areas the mechanical system applies a variable air volume system. Finally, the meeting rooms employ conditioning units that serve to circulate airflow. In total, the HVAC system uses seven air handling units, two of which are on the roof and another five are located around the building. Ductwork is generally composed of a typical rectangular, galvanized steel duct concealed by a ceiling grid.

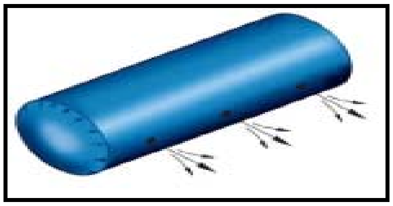
The MEP contractor for this project, Gipe Associates, declared the goal for the project was to create an efficient and state-of-the-art mechanical system that met the needs of each library space. Gipe was able to accomplish that by strategic equipment placement and efficient mechanical design. Most equipment was placed on the ground floor in order to facilitate the work of boiler units and air handling units in circulating air around the building. The desire for retail space on the ground floor created insufficient space for the housing of all the mechanical equipment in this locale. Therefore, the remainder of the mechanical units was strategically placed in mechanical rooms on each floor of the building as well as on the roof. Since there was not enough room for all of the mechanical equipment on the ground floor, due to desired retail space on the ground floor, the remainder of the mechanical units was strategically placed in mechanical rooms on each floor and on the roof. Multiple chillers were installed, instituting one unit specifically designed to handle smaller cooling loads and another to handle larger cooling needs. This ensured that both systems would be able to handle different loads at maximum efficiency. In addition, the automatic temperature control/energy management system was installed to manage the usage and rate of each mechanical unit in order to save money and energy as well as maintain a comfortable level of circulation and temperature at all times.

Through investigation, it became clear that one area of the mechanical system did not seem to reflect the theme of efficiency and comfort, namely the ductwork. Rectangular, galvanized steel ducts sufficiently meet the requirements of handling this particular HVAC system, yet it doesn’t provide any additional benefits. The purpose of this investigation is to identify an alternative ductwork scheme that would further benefit the HVAC system. It will continue to show how to implement such a scheme into the current mechanical system. The benefits that are intended to be created by this new scheme include reduced cost, improved air distribution, reduced schedule, and/or improved environmental impact.

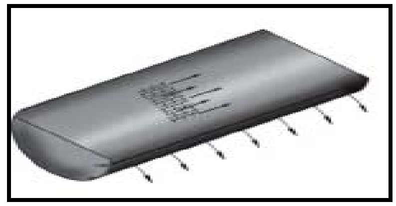
DuctSox

One alternative to the proposed rectangular, galvanized steel ductwork is a product called DuctSox. DuctSox is a unique alternative to conventional ductwork because it utilizes polyester fabric rather than metal to handle air from the mechanical equipment and disperse it around a building. DuctSox is a very versatile type of ductwork that can be customized to fit into virtually any HVAC system. It can be ordered and fabricated to meet HVAC specifications by offering several types of shapes, materials, colors, fittings, and suspension methods. In addition, this system provides reduced costs in many areas due to its low materials costs, low shipping costs, and savings in maintenance and recycling costs.

DuctSox are offered in two separate shapes that can meet the requirements of a room with an open ceiling or ceiling grid. The cylindrical series of ductwork is typically mounted horizontally or suspended from an aluminum track system in open ceiling plans. Cylindrical duct is offered in a variety of diameters that can fit into any ceiling plan the same way that a metal duct can. The alternative to exposed cylindrical DuctSox is the surface mounted series. Surface mounted DuctSox are designed to slide into any ceiling grid while still providing all of the features of an open cylindrical series. This type of duct can be installed against the wall or ceiling and has all of the fittings of typical metal ductwork.



Cylindrical DuctSox



Surface Mounted DuctSox

DuctSox can be fabricated in all of the same shapes as metallic duct as well. Elbows, transitions, T’s, and inlets of all angles can be easily created out of the fabric design. Since fabric is easier to work with than metallic duct, fittings can be customized into any shape quickly and without much cost. DuctSox ductwork is connected by zippers instead of permanent rivets or bolts which enables connections to be easily removed in order to clean or provide maintenance to the ductwork. At the same time though, the zipper connections are strong enough that the ductwork is secure and fixed in place.

DuctSox Elbows

DuctSox T-Shapes

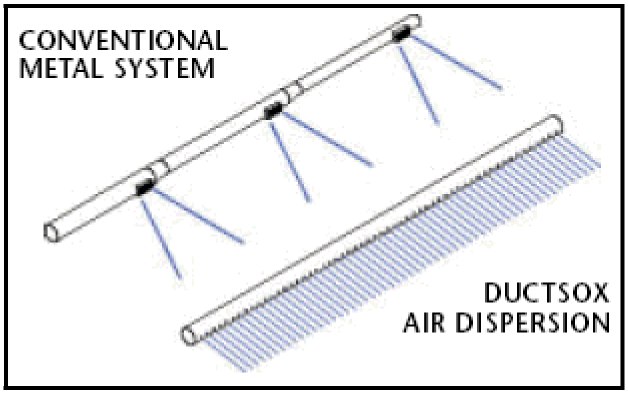
DuctSox Round End Inlet

The fabric duct is suspended with tension cables or tracks which secure it in place. Tension cables are the most affordable way to hang the ductwork, as it hangs off of the cable with clips that secure the duct and the cable together. However, in larger building spaces with the cable suspension system, pieces of angle iron must be installed

in order to properly suspend the tension cables. This will add extra cost and cause aesthetic issues in some parts of the building. The alternative is a track mounting system that allows for easy location of vertical supports and clear connection to the DuctSox below. Snap tabs are placed every 24 inches to ensure proper supports and the track is supported in the ceiling slab rather than being wall mounted like the tension cable system.

Pros & Cons of DuctSox

In the traditional metal duct system, air is discharged through diffusers spaced 5-10 ft. apart. The air is directed to specific zones, resulting in a less efficient mixing of the air in an occupied space. This inefficient mixing can cause drafts and cold or hot spots to be present in a building space. Depending on the porosity of fabric chosen, air is either dispersed in minimal throws through the fabric or through strategically sized and positioned orifices. These holes are capable of throwing air up to 90 ft. at a rate of 150 fpm, or can be adjusted to a more moderate rate which can fit the desired room comfort. With the porous fabric, ductwork, air is distributed evenly across the entire length of the ductwork without condensation or heat loss. Either way, the ductwork can target and evenly distribute air because it is both a duct and diffuser. Fabric ductwork can be customized in order to meet the requirements of comfort in any room and can provide better air distribution than metallic ductwork.



In addition to improved air distribution, DuctSox also takes a fraction of the time to be fabricated and installed compared to metallic ductwork. DuctSox is significantly lighter in weight than metal duct and is joined very simply through zippers and a snap-on track system. The only disadvantage to the DuctSox system in this area is that it will take special coordination and planning in order to install the fabric duct. Tracking and ductwork will have to be well designed and coordinated with other MEP systems or else the system can easily conflict when deflated. The fabric duct will not take shape until fully inflated which means it will take clearly defined plans (and even some imagination in the field) in order for MEP subs to understand what space the fabric duct and tracking will take up after the inflation process is complete. In addition, since many subcontractors have never worked with or around DuctSox, it will take clear explaining and possibly demonstrations to get them to understand the fabric duct coordination process. Once these barriers are crossed, DuctSox is shown to have an installation rate ten times faster than a comparable metallic duct system. This is because connections and hanging is far

simpler than typical metal ductwork because it is far lighter and more flexible than steel duct.

Fabric duct has a lot of other advantages over metal including material and shipping costs. The material cost of DuctSox is typically less expensive than metallic duct, and the savings increase as the size of the duct increases. Since there is little or no costs accrued in painting or balancing in the DuctSox installation process, there is even more savings in the entire system when compared to the costs of metallic ductwork installation. Savings are compiled even more when shipping fees are evaluated. Metallic duct is usually carried by trucks that either deliver the material to the site in sheets or in pre-fabricated units. This type of transport costs a significant amount of money due to the weight and size involved with some of the duct fittings. With DuctSox, the only thing that needs to be delivered to the site by truck is the duct connections and tracking. The cost of delivery for this material is only a fraction of the weight and cost of delivering the entire duct system. The fabric portion of the duct is pre-fabricated at the local DuctSox facility and mailed to the site (typically by UPS) thus costing an iota of typical ductwork delivery cost.

Another major advantage of the DuctSox system comes from its environmental, maintenance, and recycling advantages. From a design for disassembly angle, DuctSox are extremely beneficial because they can be easily dismantled because they have zippered and snap-on connections. This makes DuctSox easily replaceable and removable for regular cleaning and maintenance. The DuctSox can be washed like any other fabric so cleaning the system is far easier than with any metal ductwork. Regular cleaning will

lead to a much healthier and dust-free HVAC system. In addition, when any DuctSox needs to be replaced, the only labor necessary is unzipping the old duct and replacing it with a new one. All DuctSox come with a warranty for replacement ranging anywhere from one to ten years based on the material type. After removal, the DuctSox can be recycled, providing another cost benefit. In addition, many state governments give tax breaks to construction projects that use environmentally friendly products like DuctSox. Fabric duct systems are also a way to generate LEED points.

However, there are advantages and disadvantages to any system. In terms of DuctSox, there are some modifications that need to be made to the HVAC system in order to accommodate some of the fabric duct system's inabilities. First off, air handling units need to run their fans at a continuous rate in order to maintain the size and shape of the ductwork. Air flow also needs to be regulated so that pressure does not build up in the DuctSox to the point of rupture. This will not be a problem due to the Automatic Temperature Control/Energy Management System Rockville utilizes. This control system can constantly monitor and adjust the air flow of the AHUs so that the fabric duct is constantly filled to proper specifications.

Since fabric is not a good filter or noise barrier, air filters and sound isolators need to be applied to the HVAC system before air enters into the DuctSox. Moreover, there remains an issue of the personnel responsible for constructing the DuctSox system. Currently, there is no real precedence distinguishing who constructs this system. It is ultimately up to the contractor to decide who they subcontract the work out to. Typically a sheet metal contractor will take the responsibility for constructing the duct due to their familiarity in constructing ductwork. Despite these weaknesses, construction of the DuctSox system remains relatively easy, enabling just about any mechanical subcontractor to construct it.

DuctSox in Rockville Library

DuctSox in Franklin County Library

As previously stated, most of the ductwork is made of typical rectangular, galvanized steel duct that is concealed by a ceiling grid. The first step to choosing a DuctSox system in the Rockville Library would be to decide if cylindrical duct or surface mounted duct should be used. In order to use cylindrical duct properly there should not be a ceiling grid in place anywhere the fabric duct is used. Removing the ceiling grid at all levels would require a significant change in design of the entire lighting and HVAC

system. In addition there are also aesthetic ramifications of removing a ceiling grid from a building like the Rockville Library which depends heavily on visual appeal. Considering that surface mounted duct can attach to any ceiling grid and still deliver the same desired effects makes surface mounted duct the best choice.

After consulting the DuctSox representative in Maryland, the choice of fabric and air distribution recommended was the Verona comfort flow system. Verona fabric is economic, but at the same time meets the needs of the Rockville HVAC system. Verona fabric is porous and specifically accommodates the comfort flow air distribution system. The comfort flow air distribution system is a flexible method of distributing air that is quiet and low maintenance. Comfort flow design utilizes sonic vents that seals edges of a 3/16” diameter orifices to quietly and evenly distribute air to a space. The duct and vent size are both adaptable to fit into any HVAC specifications based on the desired airflow.

The following chart shows the different vent size and airflow rates for the Verona comfort series. Using these rates can determine the size and usage of the DuctSox system in order to adapt the fabric ductwork into the Rockville HVAC system.

S-Vent Size	Air Pressure	Airflow	Distance (ft.) To Velocity (FPM)		
	(W.G.)	(CFM/ft)	150	100	50
5	0.30	3.90	1.5	4	9
	0.50	5.00	2.5	5	12
	0.70	5.90	3.5	7	16
	1.00	7.07	5	9	18
10	0.30	7.70	4	7	14
	0.50	10.00	6	13	24
	0.70	11.80	9	18	33
	1.00	14.14	11	22	36
15	0.30	11.80	5	11	21
	0.50	15.00	8	17	28
	0.70	18.70	13	22	35
	1.00	21.21	14	28	38
20	0.30	15.50	7	16	27
	0.50	20.00	12	21	32
	0.70	23.70	16	26	37
	1.00	28.28	20	38	40
30	0.30	23.20	12	21	33
	0.50	30.00	16	24	36
	0.70	35.50	20	28	40
	1.00	42.43	22	43	44
40	0.30	31.00	13	23	34
	0.50	40.00	20	30	38
	0.70	47.33	22	34	43
	1.00	56.57	24	38	46

Overall with the Verona comfort flow system, hanging on track mounted hangers and mounted to the ceiling grid, can create savings of 10 – 20 % versus a sheet metal HVAC system. The Rockville Library ductwork package was priced at $ 469,856, so savings can be estimated at between $ 46,985 and $ 93,971. Additional savings can be translated from reduced schedule time since assemblage of the DuctSox HVAC system typically cuts assembly time significantly. Based on the size of the ductwork package and the labor rate of each system, it is estimated that ductwork assembly time will decrease by 45 days on each floor, to only 13 days per floor. Also, savings will be added in future maintenance and dismantling costs.

Conclusion

After significant research into the DuctSox system, it seems clear that it would be beneficial to the Rockville HVAC system. The advantages of a fabric duct system that can adapt to the needs of a library HVAC system outweigh the slight modifications that will need to be made to the mechanical system in order to accommodate DuctSox. Savings can be created from multiple sources: material cost, labor, schedule time, environmental impact, maintenance, disassembly, and more. A moderate estimate of cost savings would be about $50,000 on the ductwork package and the future cost savings can make the benefits much greater. In order to gain a greater perspective into the cost savings, an in-depth analysis would have to be done by a mechanical contractor into the adaptability of the Rockville system to fabric duct. Once the entire duct is reevaluated with the DuctSox system, this investigation claims that significant savings will be accrued.

Conclusion

The theme of each investigation is that preconstruction planning makes all the difference in not only the construction process, but in the entire life-cycle of the building. All of the savings that were accumulated from each analysis started with extensive planning before construction even began. Design for disassembly focused on creating a future deconstruction plan even before construction started. Innovative technologies need to be applied and planned to be implemented before construction begins. Any value engineering analysis has to be considered before construction on that building component begins. All of the savings from these investigations come from careful planning and mapping how to execute these savings before construction begins.

Once construction begins it is often too late to begin to create savings. Changes in the field always end up costing more than changes on paper. Most of my proposals require extending the preconstruction phase of the Rockville construction, however I feel that extending the design and planning phases of any construction process will be more beneficial than rushing through the construction process.

There are always pressures to meet a budget and schedule from an owner, yet it needs to be understood by all members of the construction team that the real savings in building cost do not come from during the construction project, but during its operation. Only 2% of the life-cycle cost of a building comes from its original construction, the remaining 98% comes from maintenance and operations cost. In order to create significant savings it needs to be understood that the more time and design considerations put into the preconstruction phase will only help the future building costs.

Appendix A

Curtainwall Takeoff

Segment	Linear Feet	Height
Bay 1	17'	58'
Bay 2	17'-3"	58'
Bay 3	17'	58'
Bay 4	18'	58'
Bay 5	17'-6"	58'
Bay 6	17'-6"	58'
Bay 7	17'	58'
Bay 8	17'-9"	58'
Bay 9	18'	58'
Bay 10	14'	58'
Bay 11	7'	58'

Total Curtainwall Length - 178'

Curtainwall Height - 58'

Curtainwall Area - 10324 ft^2

4 1/2" Curtainwall Steel Takeoff

Member	No. of Members	Member Weight (lbs/ft)	LF of Steel	Tonage
TS 12" x 4" x 3/8"	29	37.6	493	18.54
TS 14" x 6" x 3/8"	21	25.8	356	13.16
TS 12" x 4" x 1/4"	30	84.1	510	29.94

Total Tonage- 61.64 tons

10% waste factor 6.164 tons

Final Tonage- 67.8 tons

4 1/2" Curtainwall System

Steel Members - 67.8 tons

Steel Cost - $3500 per ton

Curtainwall Area - 10324 ft^2

Curtainwall Cost - $50/sf

Total Cost - $753,500

12" Curtainwall System

Curtainwall Area - 10324 ft^2
Curtainwall Cost - $90 per sf

Total Cost - $929,160

Total Savings - $175,660

Appendix B

DuctSox Air Flow

S-Vent Size	Air Pressure (W.G.)	Airflow (CFM/ft)	Distance (ft.) To Velocity (FPM) 150	100	50
5	0.30	3.90	1.5	4	9
	0.50	5.00	2.5	5	12
	0.70	5.90	3.5	7	16
	1.00	7.07	5	9	18
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	1.00	42.43	22	43	44
40	0.30	31.00	13	23	34
	0.50	40.00	20	30	38
	0.70	47.33	22	34	43
	1.00	56.57	24	38	46

Appendix C

Connection Pricing

Type Of Connection	Size	Units
Unistrut Metal Fastener	1-1/4" Diameter, 4" Long	Each
Arc Welding	1/2" Diameter, 4-1/8" Long	Each

Material Cost	Labor Cost	Equipment Cost	Total Cost
$1.74	$4.00	X	$5.73
$0.39	$0.65	$0.26	$1.30

Estimated # of Curtainwall Frame Connections	1800
Total Cost Of Arc Welding System	2340
Total Cost Of Unistrut Metal Fasteners	10314
Cost Increase	7974

Appendix D

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