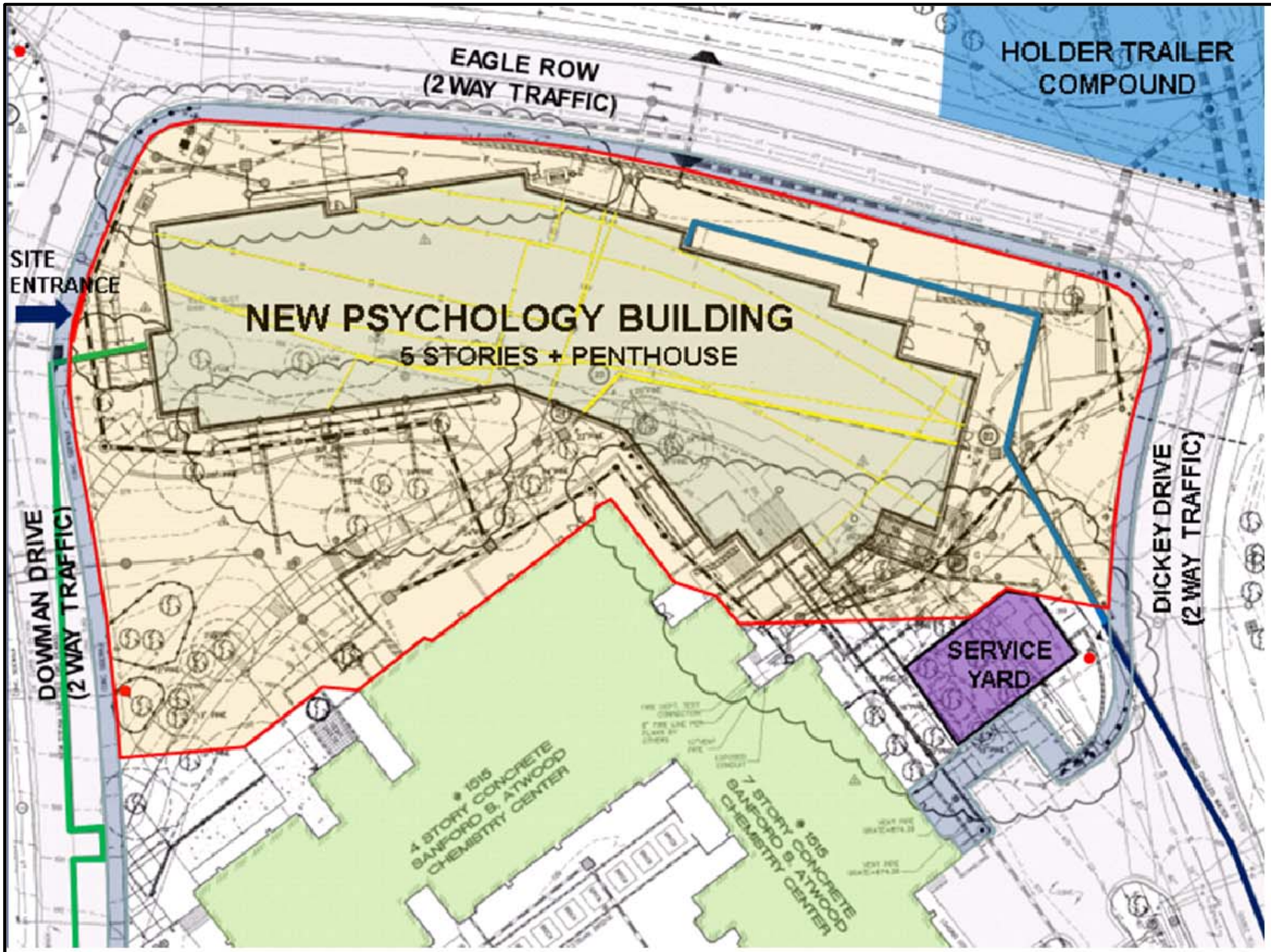
Appendix A: Site Plan of Existing Conditions



EMORY PSYCHOLOGY BUILDING ATLANTA, GA	**CONSTRUCTION SITE PLAN**	**CHRIS RENSHAW**	**SEPTEMBER 29, 2008**

Appendix B: Superstructure Site Plan

EXISTING POWER SUB STATION

STORAGE

SUB TRAILER

CONTRACTOR TRAILERS/ LIMITED PARKING

OFFICE/STOR.

HOLDER OFFICE TRAILER

OFFICE/STOR.

OFF.

OFFICE/STOR.

EMPLOYEE ENTRANCE

FIRE HYDRANT

CONSTRUCTION SITE FENCE

SHUTTLE VAN PARKING

N

EAGLE ROW

DOWMAN DRIVE

FORMWORK/ SHORING LAYDOWN

TRUCK WASH AREA

STOR.

CONSTRUCTION GATE 1

PORTABLE TOILETS

EMORY PSYCHOLOGY BUILDING
5 STORIES + PENTHOUSE

240' RADIUS

CONSTRUCTION SITE FENCE

DUMPSTER

TRUCK WASH AREA

TEMP. ROAD

TOWER CRANE

CONSTRUCTION GATE 2

CONC. TRUCK TURN AROUND

PUMP TRUCK

TEMP. ROAD

CONSTRUCTION GATE 3

REBAR/ PT TENDON LAYDOWN

DELIVERY LAYDOWN AREA

UNLOAD ZONE

DICKEY WAY

TEMP. POWER SHED

ATWOOD CHEMISTRY CENTER

FIRE HYDRANT

DUMPSTERS

4 STORIES

7 STORIES

EMORY PSYCHOLOGY BUILDING

ATLANTA, GA

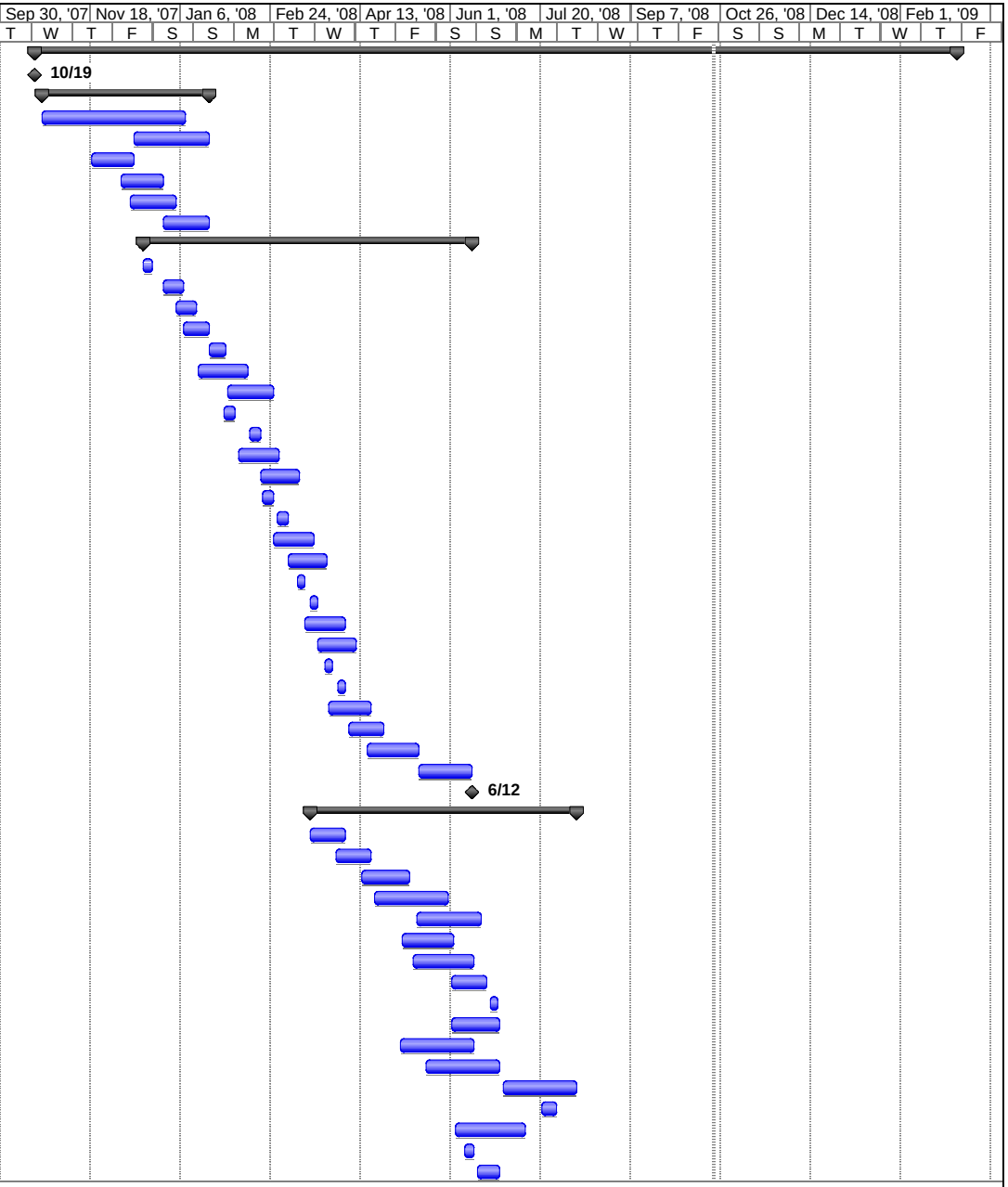
CHRIS RENSHAW

OCTOBER 24, 2008

STRUCTURE SITE PLAN

Appendix C: Overall Project Schedule

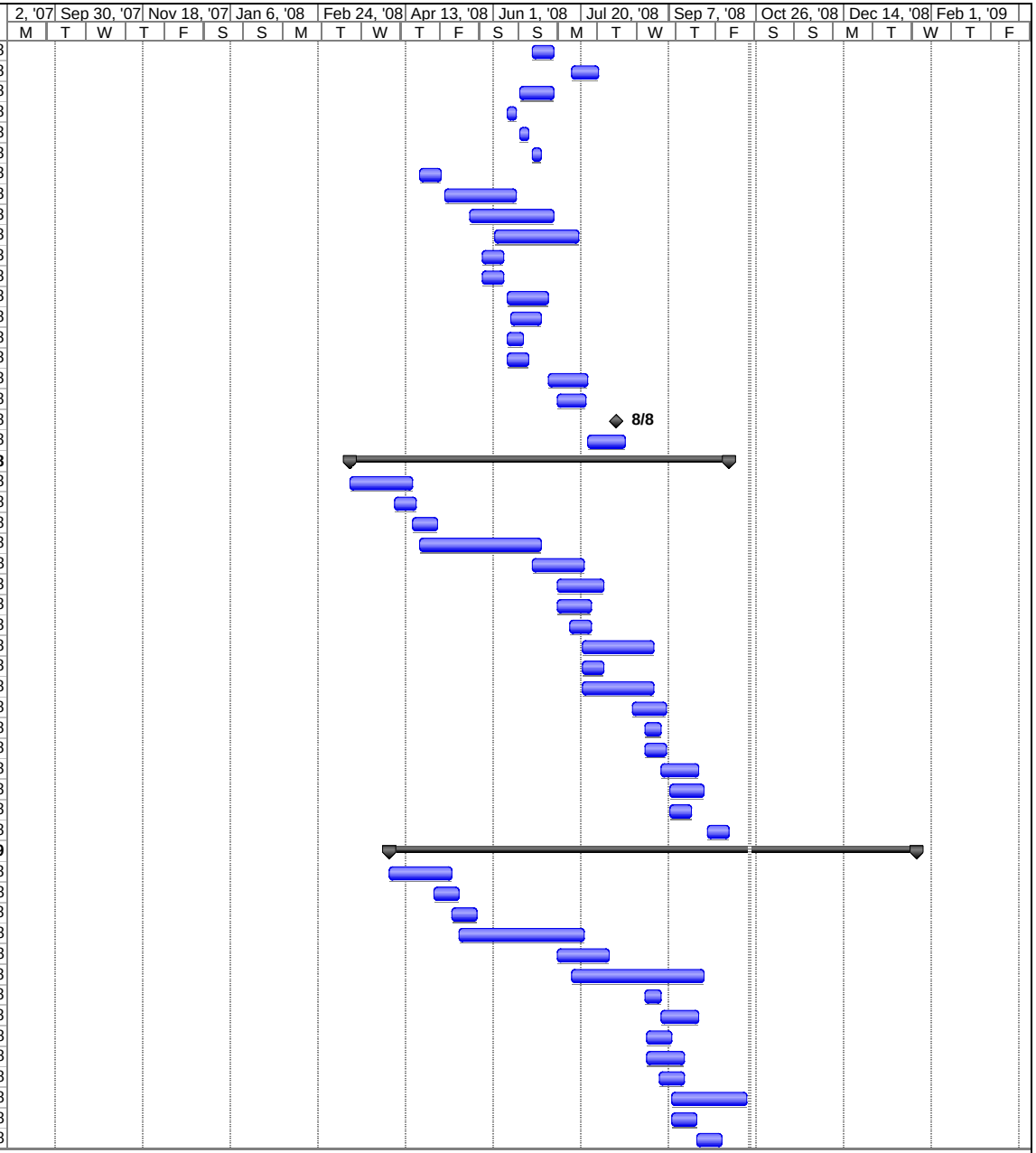
ID	Task Name	Duration	Start	Finish
1	**Emory Psychology Building**	**352 days**	**Fri 10/19/07**	**Tue 3/3/09**
2	Building Permit Obtained	0 days	Fri 10/19/07	Fri 10/19/07
3	**Substructure**	**59 days**	**Tue 10/23/07**	**Mon 1/21/08**
4	Earthwork/Site Utility Relocation	50 days	Tue 10/23/07	Tue 1/8/08
5	MEP Underground	25 days	Wed 12/12/07	Mon 1/21/08
6	Deep Foundations South	15 days	Mon 11/19/07	Tue 12/11/07
7	Deep Foundations North	15 days	Wed 12/5/07	Thu 12/27/07
8	Shallow Foundations South	15 days	Mon 12/10/07	Thu 1/3/08
9	Shallow Foundations North	15 days	Fri 12/28/07	Mon 1/21/08
10	**Superstructure**	**125 days**	**Mon 12/17/07**	**Thu 6/12/08**
11	1st Level Columns South	5 days	Mon 12/17/07	Fri 12/21/07
12	1st Level Columns North	5 days	Fri 12/28/07	Mon 1/7/08
13	SOG South	7 days	Fri 1/4/08	Mon 1/14/08
14	Electrical Underground	10 days	Tue 1/8/08	Mon 1/21/08
15	SOG North	7 days	Tue 1/22/08	Wed 1/30/08
16	2nd Level Slab South	19 days	Wed 1/16/08	Mon 2/11/08
17	2nd Level Slab North	17 days	Fri 2/1/08	Mon 2/25/08
18	2nd Level Columns South	4 days	Wed 1/30/08	Mon 2/4/08
19	2nd Level Columns North	4 days	Wed 2/13/08	Mon 2/18/08
20	3rd Level Slab South	16 days	Thu 2/7/08	Thu 2/28/08
21	3rd Level Slab North	15 days	Tue 2/19/08	Mon 3/10/08
22	3rd Level Columns South	4 days	Wed 2/20/08	Mon 2/25/08
23	3rd Level Columns North	4 days	Thu 2/28/08	Tue 3/4/08
24	4th Level Slab South	16 days	Tue 2/26/08	Tue 3/18/08
25	4th Level Slab North	15 days	Wed 3/5/08	Tue 3/25/08
26	4th Level Columns South	4 days	Mon 3/10/08	Thu 3/13/08
27	4th Level Columns North	4 days	Mon 3/17/08	Thu 3/20/08
28	5th Level Slab South	16 days	Fri 3/14/08	Fri 4/4/08
29	5th Level Slab North	15 days	Fri 3/21/08	Thu 4/10/08
30	5th Level Columns South	4 days	Tue 3/25/08	Fri 3/28/08
31	5th Level Columns North	4 days	Tue 4/1/08	Fri 4/4/08
32	Penthouse Slab South	17 days	Thu 3/27/08	Fri 4/18/08
33	Penthouse Slab North	15 days	Mon 4/7/08	Fri 4/25/08
34	Penthouse South Steel	20 days	Thu 4/17/08	Wed 5/14/08
35	Penthouse North Steel	21 days	Thu 5/15/08	Thu 6/12/08
36	Top Out Structure	0 days	Thu 6/12/08	Thu 6/12/08
37	**Exterior Skin**	**105 days**	**Mon 3/17/08**	**Fri 8/8/08**
38	1st Level Masonry	15 days	Mon 3/17/08	Fri 4/4/08
39	2nd Level Masonry	15 days	Mon 3/31/08	Fri 4/18/08
40	South Elev. Levels 3-6	20 days	Mon 4/14/08	Fri 5/9/08
41	West Elev. Levels 3-6	30 days	Mon 4/21/08	Fri 5/30/08
42	North Elev. Levels 3-6	25 days	Wed 5/14/08	Tue 6/17/08
43	South Elev. Waterproofing	20 days	Tue 5/6/08	Mon 6/2/08
44	South Elev. Stone	25 days	Mon 5/12/08	Fri 6/13/08
45	South Elev. Stucco/Glazing	15 days	Mon 6/2/08	Fri 6/20/08
46	South Elev. Curtain wall	4 days	Mon 6/23/08	Thu 6/26/08
47	South Elev. Penthouse Soffit	20 days	Mon 6/2/08	Fri 6/27/08
48	West Elev. Waterproofing	30 days	Mon 5/5/08	Fri 6/13/08
49	West Elev. Stone	30 days	Mon 5/19/08	Fri 6/27/08
50	West Elev. Stucco/Glazing	30 days	Mon 6/30/08	Fri 8/8/08
51	West Elev. Curtain wall	6 days	Mon 7/21/08	Mon 7/28/08
52	West Elev. Penthouse Soffit	28 days	Wed 6/4/08	Fri 7/11/08
53	North Elev. Waterproofing	5 days	Mon 6/9/08	Fri 6/13/08
54	North Elev. Stone	10 days	Mon 6/16/08	Fri 6/27/08



Project: Emory Detailed Schedule.mpp
Date: Wed 10/22/08

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

ID	Task Name	Duration	Start	Finish
55	North Elev. Stucco/Glazing	10 days	Mon 6/23/08	Fri 7/4/08
56	North Elev. Curtain wall	11 days	Tue 7/15/08	Tue 7/29/08
57	North Elev. Penthouse Soffit	15 days	Mon 6/16/08	Fri 7/4/08
58	East Elev. Waterproofing	5 days	Mon 6/9/08	Fri 6/13/08
59	East. Elev. Stone	5 days	Mon 6/16/08	Fri 6/20/08
60	East Elev. Stucco	5 days	Mon 6/23/08	Fri 6/27/08
61	Curtain Wall Layout	10 days	Mon 4/21/08	Fri 5/2/08
62	Curtain Wall South	30 days	Mon 5/5/08	Fri 6/13/08
63	Curtain Wall North	35 days	Mon 5/19/08	Fri 7/4/08
64	East Elev. Penthouse	35 days	Mon 6/2/08	Fri 7/18/08
65	Built Up Roof South	10 days	Mon 5/26/08	Fri 6/6/08
66	Roof Membrane South	10 days	Mon 5/26/08	Fri 6/6/08
67	Clay Tile South	17 days	Mon 6/9/08	Tue 7/1/08
68	Gutters and Downspouts South	13 days	Wed 6/11/08	Fri 6/27/08
69	Built Up Roof North	7 days	Mon 6/9/08	Tue 6/17/08
70	Roof Membrane North	10 days	Mon 6/9/08	Fri 6/20/08
71	Clay Tile North	16 days	Wed 7/2/08	Wed 7/23/08
72	Gutters and Downspouts North	12 days	Mon 7/7/08	Tue 7/22/08
73	Building Dry In	0 days	Fri 8/8/08	Fri 8/8/08
74	Penthouse Steel Spray on	15 days	Thu 7/24/08	Wed 8/13/08
75	**1st Floor Interior**	**152 days**	**Thu 3/13/08**	**Fri 10/10/08**
76	MEP/Spk. Overhead Rough Ins	25 days	Thu 3/13/08	Wed 4/16/08
77	Wall Framing/Door Frames	10 days	Mon 4/7/08	Fri 4/18/08
78	Bathroom Plumbing Rough In	10 days	Thu 4/17/08	Wed 4/30/08
79	Electrical Rough In/Pull Wire	50 days	Mon 4/21/08	Fri 6/27/08
80	Walls and Insulation	21 days	Mon 6/23/08	Mon 7/21/08
81	Duct and Plumbing Insulation	20 days	Mon 7/7/08	Fri 8/1/08
82	Install ACT Grid/Frame Gyp. Ceiling	15 days	Mon 7/7/08	Fri 7/25/08
83	Hang Drywall/Finish	10 days	Mon 7/14/08	Fri 7/25/08
84	Set Spk. Heads/Light Fixtures/Diffus	30 days	Mon 7/21/08	Fri 8/29/08
85	Prime Paint	10 days	Mon 7/21/08	Fri 8/1/08
86	Ornamental Staircase	30 days	Mon 7/21/08	Fri 8/29/08
87	Finish Paint/Drop ACT	15 days	Mon 8/18/08	Fri 9/5/08
88	Bathroom Tile/Countertops	7 days	Mon 8/25/08	Tue 9/2/08
89	Terrazzo Flooring	10 days	Mon 8/25/08	Fri 9/5/08
90	Bathroom Partitions/Fixtures/Finishe	15 days	Wed 9/3/08	Tue 9/23/08
91	Carpet/Linoleum	15 days	Mon 9/8/08	Fri 9/26/08
92	Millwork	10 days	Mon 9/8/08	Fri 9/19/08
93	Interior Glazing and Door Installation	10 days	Mon 9/29/08	Fri 10/10/08
94	**2nd Floor Interior**	**211 days**	**Fri 4/4/08**	**Fri 1/23/09**
95	MEP/Spk. Overhead Rough Ins	25 days	Fri 4/4/08	Thu 5/8/08
96	Wall Framing/Door Frames	10 days	Tue 4/29/08	Mon 5/12/08
97	Bathroom Plumbing Rough In	10 days	Fri 5/9/08	Thu 5/22/08
98	Electrical Rough In/Pull Wire	50 days	Tue 5/13/08	Mon 7/21/08
99	Duct and Plumbing Insulation	21 days	Mon 7/7/08	Mon 8/4/08
100	Terrazzo Flooring	54 days	Tue 7/15/08	Fri 9/26/08
101	Bathroom Tile/Countertops	7 days	Mon 8/25/08	Tue 9/2/08
102	Bathroom Partitions/Fixtures/Finishe	15 days	Wed 9/3/08	Tue 9/23/08
103	Walls and Insulation	10 days	Tue 8/26/08	Mon 9/8/08
104	Install ACT Grid/Frame Gyp. Ceiling	15 days	Tue 8/26/08	Mon 9/15/08
105	Hang Drywall/Finish	10 days	Tue 9/2/08	Mon 9/15/08
106	Set Spk. Heads/Light Fixtures/Diffus	30 days	Tue 9/9/08	Mon 10/20/08
107	Prime Paint	10 days	Tue 9/9/08	Mon 9/22/08
108	Wood/Fabric Panels	10 days	Tue 9/23/08	Mon 10/6/08



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Task
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Milestone
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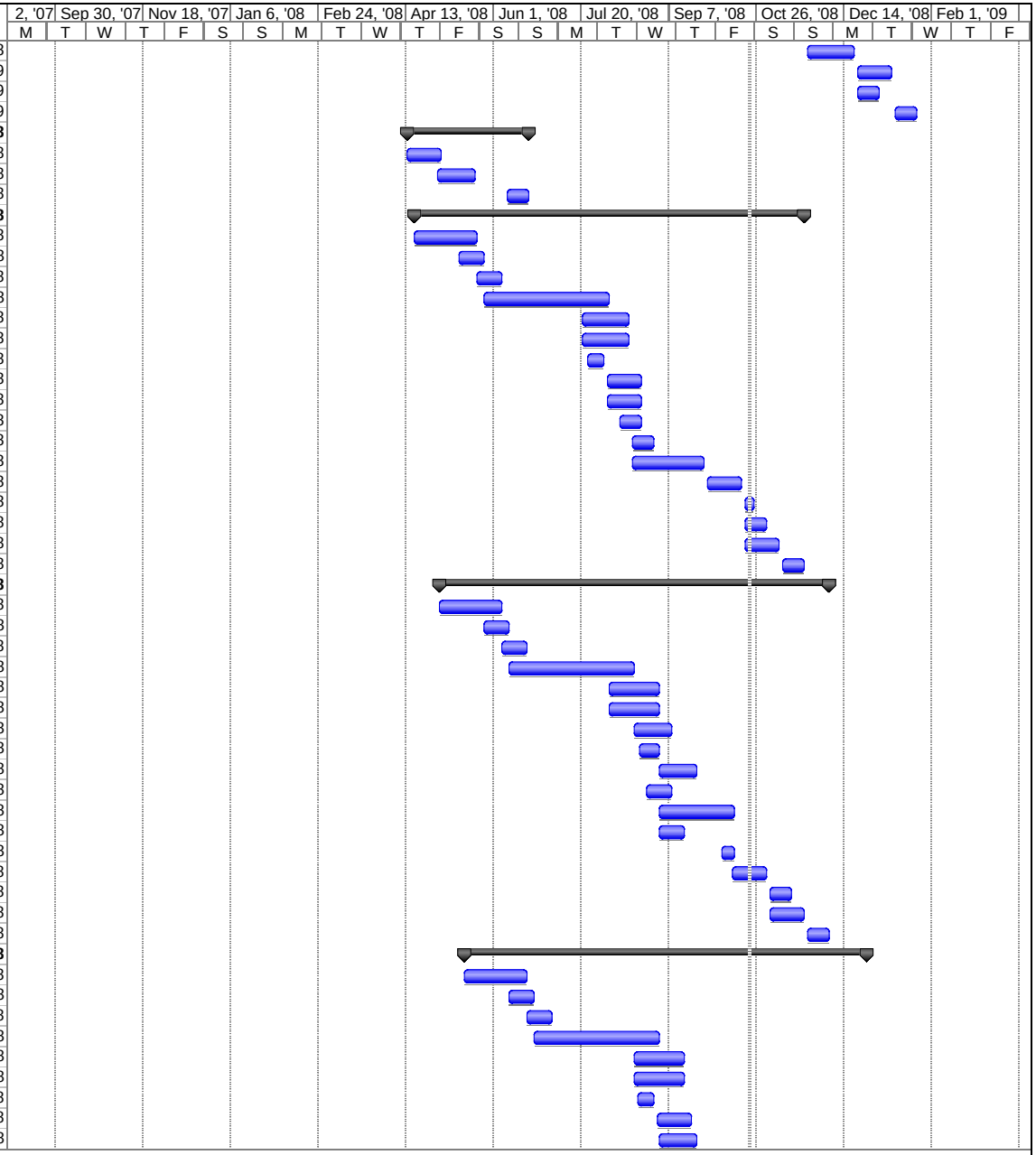
External Milestone
Deadline

ID	Task Name	Duration	Start	Finish
109	Finish Paint/Drop ACT	20 days	Mon 11/24/08	Fri 12/19/08
110	Carpet/Linoleum	15 days	Mon 12/22/08	Fri 1/9/09
111	Millwork	10 days	Mon 12/22/08	Fri 1/2/09
112	Interior Glazing and Door Installation	10 days	Mon 1/12/09	Fri 1/23/09
113	**Stairs**	**50 days**	**Mon 4/14/08**	**Fri 6/20/08**
114	North Stairs	15 days	Mon 4/14/08	Fri 5/2/08
115	Central Stairs	15 days	Thu 5/1/08	Wed 5/21/08
116	South Stairs	10 days	Mon 6/9/08	Fri 6/20/08
117	**3rd Floor Interior**	**156 days**	**Fri 4/18/08**	**Fri 11/21/08**
118	MEP/Spk. Overhead Rough Ins	25 days	Fri 4/18/08	Thu 5/22/08
119	Wall Framing/Door Frames	10 days	Tue 5/13/08	Mon 5/26/08
120	Bathroom Plumbing Rough In	10 days	Fri 5/23/08	Thu 6/5/08
121	Electrical Rough In/Pull Wire	50 days	Tue 5/27/08	Mon 8/4/08
122	Walls and Insulation	20 days	Mon 7/21/08	Fri 8/15/08
123	Duct and Plumbing Insulation	20 days	Mon 7/21/08	Fri 8/15/08
124	Bathroom Tile/Countertops	7 days	Thu 7/24/08	Fri 8/1/08
125	Bathroom Partitions/Fixtures/Finishe	15 days	Mon 8/4/08	Fri 8/22/08
126	Install ACT Grid/Frame Gyp. Ceilings	15 days	Mon 8/4/08	Fri 8/22/08
127	Hang Drywall/Finish	10 days	Mon 8/11/08	Fri 8/22/08
128	Prime Paint	10 days	Mon 8/18/08	Fri 8/29/08
129	Set Spk. Heads/Light Fixtures/Diffus	30 days	Mon 8/18/08	Fri 9/26/08
130	Finish Paint	15 days	Mon 9/29/08	Fri 10/17/08
131	Drop ACT	5 days	Mon 10/20/08	Fri 10/24/08
132	Millwork	10 days	Mon 10/20/08	Fri 10/31/08
133	Carpet/Linoleum	15 days	Mon 10/20/08	Fri 11/7/08
134	Interior Glazing and Door Installation	10 days	Mon 11/10/08	Fri 11/21/08
135	**4th Floor Interior**	**156 days**	**Fri 5/2/08**	**Fri 12/5/08**
136	MEP/Spk. Overhead Rough Ins	25 days	Fri 5/2/08	Thu 6/5/08
137	Wall Framing/Door Frames	10 days	Tue 5/27/08	Mon 6/9/08
138	Bathroom Plumbing Rough In	10 days	Fri 6/6/08	Thu 6/19/08
139	Electrical Rough In/Pull Wire	50 days	Tue 6/10/08	Mon 8/18/08
140	Walls and Insulation	20 days	Tue 8/5/08	Mon 9/1/08
141	Duct and Plumbing Insulation	20 days	Tue 8/5/08	Mon 9/1/08
142	Install ACT Grid/Frame Gyp. Ceilings	15 days	Tue 8/19/08	Mon 9/8/08
143	Bathroom Tile/Countertops	7 days	Fri 8/22/08	Mon 9/1/08
144	Bathroom Partitions/Fixtures/Finishe	15 days	Tue 9/2/08	Mon 9/22/08
145	Hang Drywall/Finish	10 days	Tue 8/26/08	Mon 9/8/08
146	Set Spk. Heads/Light Fixtures/Diffus	30 days	Tue 9/2/08	Mon 10/13/08
147	Prime Paint	10 days	Tue 9/2/08	Mon 9/15/08
148	Drop ACT	5 days	Tue 10/7/08	Mon 10/13/08
149	Finish Paint	15 days	Mon 10/13/08	Fri 10/31/08
150	Millwork	10 days	Mon 11/3/08	Fri 11/14/08
151	Carpet/Linoleum	15 days	Mon 11/3/08	Fri 11/21/08
152	Interior Glazing and Door Installation	10 days	Mon 11/24/08	Fri 12/5/08
153	**5th Floor Interior**	**161 days**	**Fri 5/16/08**	**Fri 12/26/08**
154	MEP/Spk. Overhead Rough Ins	25 days	Fri 5/16/08	Thu 6/19/08
155	Wall Framing/Door Frames	10 days	Tue 6/10/08	Mon 6/23/08
156	Bathroom Plumbing Rough In	10 days	Fri 6/20/08	Thu 7/3/08
157	Electrical Rough In/Pull Wire	50 days	Tue 6/24/08	Mon 9/1/08
158	Walls and Insulation	20 days	Tue 8/19/08	Mon 9/15/08
159	Duct and Plumbing Insulation	20 days	Tue 8/19/08	Mon 9/15/08
160	Bathroom Tile/Countertops	7 days	Thu 8/21/08	Fri 8/29/08
161	Bathroom Partitions/Fixtures/Finishe	15 days	Mon 9/1/08	Fri 9/19/08
162	Install ACT Grid/Frame Gyp. Ceilings	15 days	Tue 9/2/08	Mon 9/22/08



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Task
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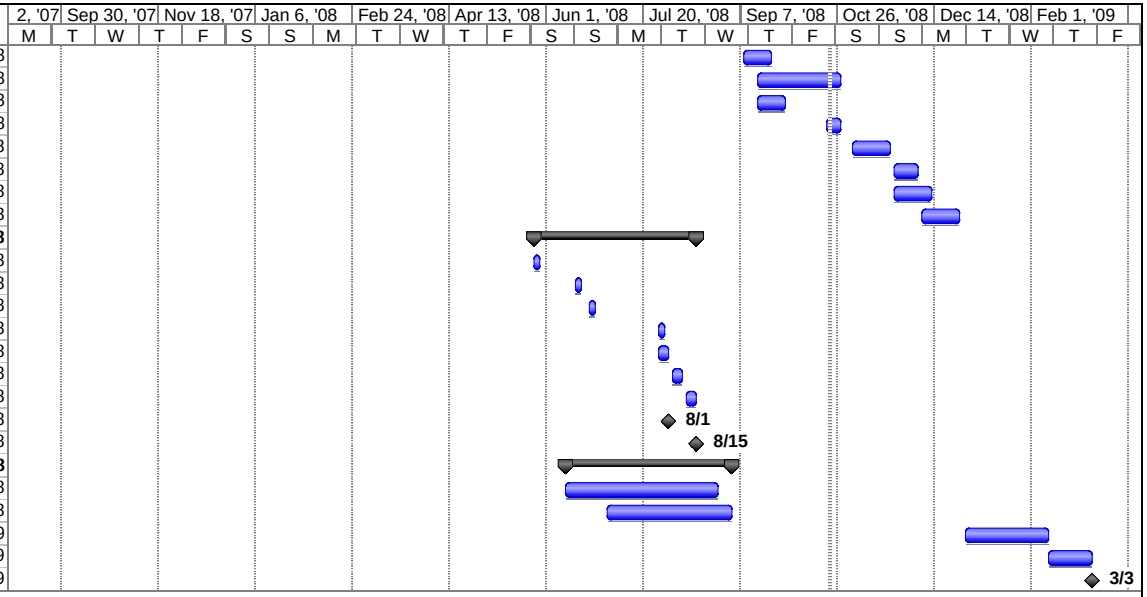
Deadline

ID	Task Name	Duration	Start	Finish
163	Hang Drywall/Finish	10 days	Tue 9/9/08	Mon 9/22/08
164	Set Spk. Heads/Light Fixtures/Diffus	30 days	Tue 9/16/08	Mon 10/27/08
165	Prime Paint	10 days	Tue 9/16/08	Mon 9/29/08
166	Drop ACT	5 days	Tue 10/21/08	Mon 10/27/08
167	Finish Paint	15 days	Mon 11/3/08	Fri 11/21/08
168	Millwork	10 days	Mon 11/24/08	Fri 12/5/08
169	Carpet/Linoleum	15 days	Mon 11/24/08	Fri 12/12/08
170	Interior Glazing and Door Installation	15 days	Mon 12/8/08	Fri 12/26/08
171	**MEP Installation/Start Up**	**60 days**	**Mon 5/26/08**	**Fri 8/15/08**
172	Automatic Transfer Switch	3 days	Mon 5/26/08	Wed 5/28/08
173	Set 25 KV Loop Switch	3 days	Mon 6/16/08	Wed 6/18/08
174	Transformer	3 days	Mon 6/23/08	Wed 6/25/08
175	Generator	3 days	Mon 7/28/08	Wed 7/30/08
176	Energize 25 KV Loop Switch	5 days	Mon 7/28/08	Fri 8/1/08
177	AHU & ERU Start Up	5 days	Mon 8/4/08	Fri 8/8/08
178	Chill Water Start up	5 days	Mon 8/11/08	Fri 8/15/08
179	Permanent Power	0 days	Fri 8/1/08	Fri 8/1/08
180	Conditioned Air	0 days	Fri 8/15/08	Fri 8/15/08
181	**Elevators**	**60 days**	**Wed 6/11/08**	**Tue 9/2/08**
182	4500 lb Elevator	55 days	Wed 6/11/08	Tue 8/26/08
183	3500 lb Elevator	45 days	Wed 7/2/08	Tue 9/2/08
184	Lansdscaping	30 days	Tue 12/30/08	Mon 2/9/09
185	Occupancy	16 days	Tue 2/10/09	Tue 3/3/09
186	Substantial Completion	0 days	Tue 3/3/09	Tue 3/3/09



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Appendix D: BIM Practices by Construction Manager

Holder BIM Practices

Each project that Holder either bids for or is asked to build is assessed for BIM use. The first step is a BIM Assessment and Planning Meeting where they decide whether BIM services will be appropriate or not. Following this meeting there is another meeting with the preconstruction department which performs a similar assessment. The specifics that the team is looking for are:

- Staffing resources
- Cost benefit of BIM use
- Building type
- If the owner is bought in
- Other project team players
- Subcontractor ability to model in 3D

The experience of Holder has shown that even if they absorb some of the upfront costs of BIM, they acceleration in coordination and reduced field clashes will still pay off. If the owner is bought into BIM use, they may pick up the BIM costs as a pre-construction services fee.

Once the project has been given the go ahead to use BIM, the BIM department will create the model from 2D architect's drawings. Unlike the Psychology Building, most architects do not model their designs. Holder will also model the MEP systems since most engineers also do not use 3D modeling. The first place that the model is actually used is in the business development department to show the phasing of the project. The model is combined with a schedule using Naviswork's Timeliner as part of the business development.

The specific BIM coordination requirements and submission of models is written into the contracts of subcontractors. The coordination process starts during pre-construction and involves Holder, the architect, engineers, and necessary subcontractors. The coordination starts early so that the subcontractors can learn the ways that they have to use BIM and be fully self-sufficient by the time construction starts. Training is necessary by the Holder BIM department in some cases. Holder would like the MEP subcontractors to produce their own models once they have a grasp on the software. Until then, Holder must create the model and not simply just manage it.

The files for the model are kept in the main office, with an FTP site that may be accessed from anywhere with internet connection. This is how the field staff accesses the model and finds updates. Holder has a BIM field coordinator onsite to manage the model during construction. The costs for this person, creation of the model, and pre-construction BIM services are charged to the project, while the business development is charged as corporate overhead.

Holder also uses the model for quantity take offs. For verification, they also estimate quantities using traditional methods. Usually the model is created by Holder for estimation. Even if the architect designed in 3D, the model is not always usable for estimation and has to be recreated.

Holder hands the model over to the owner after the project is complete. This is an as built model but it can also be modified to include facility management services. The services are provided at an extra fee but include equipment manuals, warranties, and other information that they owner may need.

Although Holder has used BIM very well, there is still a learning curve associated with it. As recent as the Psychology Building, Holder was using Navisworks in a way that was inefficient. They have since fixed this and learned from their mistakes. Other than that, Holder claims that they see no pitfalls of BIM and fully support its use on their projects. They continue to learn more about BIM and what they can add to it as they continue to use it.

One thing that was mentioned that could have been used more frequently was a smart board. The smart board allows the user to project the model onto the board and navigate it through a computer. The board can be written on with a marker, then the mark ups can be printed off along with what else is on the screen. Holder feels that the use of this more often would have caused more efficiency.

Also, Holder would like to have the model be more accessible to all the workers who may need it onsite. Currently, if there is a coordination problem that needs to be visualized on the model, the worker must talk to their foreman, the foreman must go to Holder's trailer, and someone must bring up the model to look up the problem. A portable kiosk would eliminate this path and bring the worker directly to the model. The kiosk would be on site and available to all workers to use. The workers could solve their own problems immediately and be more efficient.

Construction Manager A BIM Practices

Construction Manager A analyzes the risks involved with each project before they decide to use BIM. The largest risk that they face is cost; if using BIM will eventually pay for itself on the project through increased coordination and a reduction in field clashes. Specifically what they look for is:

- MEP Complexity
- Site Logistics
- Structural Steel (complexity and quantity)
- Façade (complexity)
- Subcontractor Availability

There are several costs associated with the model and it must be established whether the model can be used for all of these things and pay off as well. CM A does not create the model in house and instead contracts a third party to create it for them. Also, CM A rarely finds an architect that designs in 3D and assumes that if they are going to use BIM that they will have to pay to have the model created. For them, the architect does not play a large role and while it is somewhat easier to be on a project earlier, it does not make or break the project. CM A is writing language into the contract to make sure that contractors will provide their models in the file types that they require. They are also finding that more owners are starting to get on board with BIM, but they still don't know how to articulate what they want from the model.

Some of the things that CM A likes about BIM are that it makes processes faster when they track RFIs and change bulletins to the model. The problems or unclear issues that may take a long time to describe can be shown easily through the model. This makes it easier to solve the problem, and get it worked out in the field. It also makes it easier to determine what work they are contracted to do and what they may be asked to do, but are not actually contractually obligated. They can bring this to the attention of the owner or contractor before the work gets done instead of rushing to do it and having to worry about who will pay for it afterwards.

One of the things that this CM has found extremely useful is tracking of materials through the model. Basically any material can be tracked, but this CM has had much success with tracking steel members on projects that are very large ($100 million +). The members can be tracked using bar codes, similar to how delivery companies like Fedex track packages. The model can actually display what that member is and what date it is scheduled to be delivered to site.

The software that they are using for this kind of tracking is actually fairly widely used throughout the construction industry. It is called Vela Systems and it was developed by an architect who had field experience. The software is used by so many because it is user friendly and reliable. They have been able to track steel as well as other long lead items that have the potential to be problematic. For one project it was used to track the façade shipments because the façade was composed of integral cast stone which was complex had a specific arrangement to be constructed. Through the model each component could be tagged to ease confusion during construction and ensure the quality that they desired.

Another innovation CM A is implementing is electronic closeout using BIM. Instead of collecting paper closeout documents and handing them over to the owner, CM A would like to have all these items linked to the model in PDF format. The documents would include owner's manuals, warranties, insurance information, and preventative maintenance information. The goal is to link the software to preventative maintenance software so that the model could tell the owner when they need to perform preventative maintenance, or if a warranty may soon expire. The model can actually be loaded onto a tablet PC, which can be carried around the building while doing inspections. The tablet PC has the ability to take notes, record audio, and take pictures. This would be used primarily by the end user's maintenance staff, but could also be used by CM A during construction for punch listing. This application is being implemented on a current project that has yet to reach the close out phase.

CM A thinks that there is still more that they could be using the model for. For instance, the model could be updated to show inspections of ducts and pipes throughout the building. The model would then easily display what has been inspected and what still needs to be inspected.

One of the pitfalls of BIM, although small, is that the model can hold too much information. The model has information for a lot of people, from the duct fabricators to the owner, but those people do not require the same information. The owner will not care what gauge the ductwork is, but the information is likely to be carried through the model and increase the file size. It is important for the CM to realize the owner's needs and adjust the model information accordingly.

Another challenge is that there are so many new technologies emerging that it is difficult to sift through them and find what will work best for their needs. Also, as a large company, the upper management wants to set guidelines and rules for using BIM, but they will not necessarily work for each project. Success with BIM on one project, for one application, may be a waste of time on another project for the same thing. Each project is unique, and the approach to BIM must be unique as well. If the use of BIM is forced, it will not present the amount of success that it is capable of achieving. There also has to be an understanding that the first couple of projects using BIM may not be profitable at first, but the payback will come learn after the users have passed the learning curve.

Construction Manager B BIM Practices

Construction Manager B's approach to BIM is slightly different than other CMs. They see potential to use BIM on every project. Their view is that even if BIM is only used for a small part of a small project, it will probably still help that project. Even if the magnitudes of the benefits are not as large, the benefit is there nonetheless. Their objective is to find out what part of a project may benefit from BIM, in apply BIM in any way that may help. The overarching goal is to use BIM in some way on every project.

The complexity of how building systems is somewhat of a factor in their decision making, but it is not the only thing. A project with a complex MEP system and tight spaces to fit it in would obviously benefit from using BIM, but it is not the only type of project that will benefit. A smaller project may have less coordination to do, but it will also have less time to invest with the model, so it still may be worthwhile to use BIM.

They start to think about how they may be able to use BIM while reviewing the RFP. The earlier that they know how there are going to use BIM, the sooner they can get the ball rolling and start to collect information that will help them build the model and apply information to it. Like on the Psychology Building, if much of the work can be completed in pre-construction, the construction phase will go smoother.

CM B is still finding that owners are apprehensive about using BIM. They have heard a lot about it, but what they have heard is that it is expensive and the benefits are hard to quantify. Their lack of BIM knowledge prevents them from wanting to implement BIM on projects, not necessarily the cost. Even if they do want to use BIM, they are still unsure about what that means, how to get it, and how to ask for it.

Like Holder, CM B assesses the project "players" when looking how to implement BIM. They use past experience and look at what the other players are required to provide to make their decision. For instance, the architect may be required to provide a model, which would immediately make the project a good candidate for BIM use. Knowledge of the owner, engineers, and subcontractors also helps because the whole group will work as a collaborative team with the BIM. Without full cooperation and collaboration, it is almost impossible for a BIM project to reach its full potential.

CM B will use the model that an architect has created if it is available but is also capable of creating a model on their own. Getting the model from the architect can give the CM a head start on their on BIM even if there is no information linked to it. It is a help, but whether the CM gets the model from the architect or not is not going to determine whether or not they use BIM. Another thing that may affect the architect's model is interoperability. The program that the architect is using may not always be useful for

CM B and what they want to use it for, so they may have to create a new model anyway. Interoperability is always a concern since there are always new products coming out, but there are enough people paying attention to interoperability that problems are becoming less and less frequent. Subcontractors are expected to create a model of their own system for clash detection.

In addition to clash detection, CM B has been able to use BIM for 4D modeling (for proposal presentation, assessing schedule scenarios, and virtual mock-ups), material tracking, and automated quantity estimating. CM B has been very happy with the results of all their applications of BIM and predict that there will be even more uses in the future, they just have not thought of them yet.

CM B is realizing the benefits of BIM in several ways. Clash detection decreases field modifications and improves field productivity; 4D modeling improves understanding by visualization; automated material estimating decreases the time it takes to complete a material take-off. However, BIM's greater positive effect is on a broader level. BIM is facilitating integrated project delivery, an approach where owners, architects, engineers, contactors, and subcontractor together form an integrated project team. This is a fundamental change from tradition in how a team is structured and how information is shared and exchanged. It promotes a level of collaboration that really allows the specific benefits of BIM to be realized.

For CM B, BIM is something that could be implemented on every project at some point, but that point still may be 15-20 years away. They view BIM as CAD was viewed several years ago. At first it was slow to catch on, but eventually it became used industry wide. Of course, that means BIM could be overtaken by another tool several years from now and become obsolete itself.

Most of the issues that CM B has faced with BIM thus far have stemmed from either lack of experience with the new software and tools or from software limitations. The industry as a whole is still towards the beginning of the learning curve, so lack of experience with the tools can impede success. BIM technologies and programs are also fairly new and not necessarily time-tested. As experience is gained with the tools, the limitations are discovered. Communicating these limitations back to the developers helps mold future versions of the technologies.

Construction Manager C BIM Practices

Construction Manager C was asked about how they are using BIM on a large, multi-phased hospital project. CM C has been the contractor for every phase, but they did not implement BIM until the second phase. Each phase was awarded separately, so it was hard to tell if BIM would have been cost effective on the first phase. At the start of the second phase CM C realized that there was a tool available that could save time and money on the complex job. It was at that time that they decided to convince the owner and subcontractors that BIM was they way to go for the project.

CM C has a BIM department, but they do not create the model. The modeling services are purchased from a third party contractor who converts the architect's and structural engineer's drawings from 2D to 3D. The subcontractors then received the model and updated their discipline to it. CM C's BIM department works out of their regional office and attempts to sell owners on the benefits of BIM.

There was a premium to pay by starting a new group on BIM use. The premium comes by having to educate the subcontractors, purchase the model, purchase the clash detection programs, and making sure the subcontractors are up to speed and know what is expected of them. The CM believes that with the superior coordination, the BIM has already more than paid for itself.

The BIM use on this building started with MEP coordination. The interstitial floors of the hospital contained complex MEP systems that were tightly fitted into the space. BIM was used to make sure that everything fit with no clashes. With the success of those areas, CM C decided to use the BIM in more ways. There was a pavilion area with a lot of materials and different building aspects coming together that was hard to visualize from the 2D drawings. The CM C project executive decided that using BIM was worth a shot since it had been so successful before. Right away, the BIM revealed that there was a gutter running through the façade's stone through several parts of the building. The stone that arrived on site was pre-cut, so if the BIM did not catch this, the stone would have all been delivered and ready to install, but would have had to been cut on site. This would've led to an enormous cost increase and a considerable delay to the schedule. Instead, it was sorted out in the model and the stone cutters were able to cut the stone offsite.

The subcontractors on the project also realize the benefits of BIM use. Although displeased with having to change at first, they soon found that the BIM was saving them time and money. There was an initial learning curve, but the time and material savings in the field were tremendous. One mechanical contractor mentioned that they hadn't had to take even a pickup truckload of wasted piping out of the building due to field clashes and rework. For a building with a mechanical package coming in at around $90 million, that is saying something. Another mechanical contractor, a 30 year veteran, said that without BIM there was absolutely no way that they would have been able to get air handlers into the interstitial spaces with traditional methods. CM C estimates that 90% of the contractors are very impressed with BIM and that they will not go back to their traditional methods.

One small problem that CM C has seen with the BIM use is the owner's expectations. The owner paid for the modeling and clash detection, saw the model and was under the impression that there would be zero field clashes and would not have to pay a dime for additional delays or design problems. With today's technology, this is simply not practical. The BIM is very accurate and will greatly reduce field clashes, but there is no guarantee that it will catch them all.

CM C started using BIM on larger projects, but is starting to see the usage trickle down to smaller buildings. They see BIM is a tool that can help them build better. Since there is so much hype around BIM and it is widely talked about it, they first must understand what is tangible and what can be used for each project. They also see that investing in BIM now is one of the smartest things a CM and the subs can do. After the recession the prediction is that there will be an explosion in the number of projects being built. If the contractors want to get a piece of the pie, they need to have the tools in place already so they can get jobs, build them faster and move on to the next ones.

Appendix E: Construction Manager BIM Practices Comparison Chart

	Holder	CM A	CM B	CM C	Psychology Building
First Inquiry	BIM Assessment Meeting, during RFP review	During RFP review	During RFP Review	After risks are analyzed	During RFP review, architect already using BIM
Risks Analyzed	Building type, if owner is bought in, what other players are involved, if the trade contractors are using 3D	MEP Complexity, site logistics, structural steel quantity and complexity, architectural complexity, subcontractor availability	Overall look at building to find BIM potential, project players, requirements of other players, complex coordination	Complex MEP systems, architectural complexity	Owner was already on board, architect was already using BIM, very few extra risks to analyze
Production of the model	BIM Department creates model	Third party creates model	BIM Department capable of creating model if not provided by architect	Third party creates model	Architect Created
Architect Provided Model	Rare	Very Rare	Sometimes	Very Rare	Yes
Subcontractor Model Creation	Expected to create model for their discipline	Expected to create model for their discipline	Expected to create model for their discipline	Expected to create model for their discipline	Yes, each discipline created own model
Owner Reactions	Positive	Like BIM but still don't know a lot about it and can't always articulate wha they want from the model	Tend to be apprehensive, lack of awareness prevents them from wanting to use BIM, not cost	High expectations, expect zero field clashes since they have paid for software to eliminate this problem	Positive, enthusiastic, anticipate using BIM exclusively in the near future
MEP Clash Detection	Most common use	Most common use	Most common use	Primary Use	Used
IPD	Used if possible, but will not make or break the project	Used if possible, but will not make or break the project	Seen as a major benefit of using BIM, like to get as many project players on board early as possible	Unclear if used or not	Implemented and proved to be very successful
Material Tracking	Not used	Used frequently, a major part of the BIM implementation	Used if right for the project	Not used	Not used
Facilities Management	Has the capability, will use if owner feels the need, internally created software program to link O&Ms, warranties to the model	Tracking manuals, warranties, and insurance info to equipment, also implementing preventative maintenance software linked to BIM for owner	Used on some projects but unknown as to what degree	Unclear if used or not	Model given to Emory, but without FM software linked to it
Subcontractor Reaction	Have been met with little resistance, subcontractors benefit from learning	Positive, some contractors have been 3D modeling for years	Positive, some contractors have been 3D modeling for years	Skeptical at first but now realizing benefits after being past learning curve	Positive, mechanical contractor plans on using BIM for prefabrication in the future

	Holder	CM A	CM B	CM C	Psychology Building
4D	Have been using for planning and visualization successfully	Using 4D and even 5D (cost) for some projects	Using for proposal presentations, assessing schedule scenarios, and virtual mockups	Unclear if used or not	Used for planning different stages of the project and visualization to Emory
Estimation	Used but verified through traditional methods	Used but verified through traditional methods	Used but verified through traditional methods	Not used	Used but verified through traditional methods, Emory also contracted a separate estimator
Problems	Navisworks was not used as effectively as it could have been in the past	Corporate mentality limits experimental usage of BIM and different technologies	Interoperability can be an issue but enough people are aware of it now that it can be worked around	Very few problems, educating subcontractors was necessary to make them effective	Very few problems, the model wasn't as accessible onsite as was expected, but did not pose any problems
Room for Improvement	Using resources effectively, smartboard usage could have been increased	Unlinking old information from the model that is no longer necessary	Industry as a whole is still in the beginning of the learning curve, technology and expertise is developing	Implenting BIM earlier on in the project timeline	More use of smartboard to convey ideas
Possible New Uses	Kiosk onsite for general use	Linking inspections of duct and pipe to the model for easy visualization	Undetermined, many possible uses, new projects will bring along new methods	None presented	MEP contractor plans to use 3D model for fabrication
RFIS	Saw increase in speed of response due to visual aids	Reduction in number and time of response	Undetermined, assumed to reduce number	Decrease in number of RFIs	Saw increase in speed of response due to visual aids
Getting on Board Early	It is a help to be on earlier since things can get started and ironed out faster, but not crucial	Getting on board earlier allows for more uses early on such as 4D and 5D, estimating and value engineering	Imperative to get started as early as possible to add as much data to the model as possible	Better to get on earlier and be past learning curve by the time construction is in full operation	Entire team was brought on very earler which helped tremendously
Strongest Benefits	Experience has led to more ideas for new uses and awareness allows them to adapt technology to fit their needs	Use of material tracking and preventative maintenance software is enabling them to give the owner more of what they want	BIM facilitates IPD which helps to promote enhanced communication and will ultimately make building more efficient	Coordination on very complex and large project has made benefits huge on such a large scale	Architect and CM were both brought on board early and all players were willing to learn and use BIM to its full potential

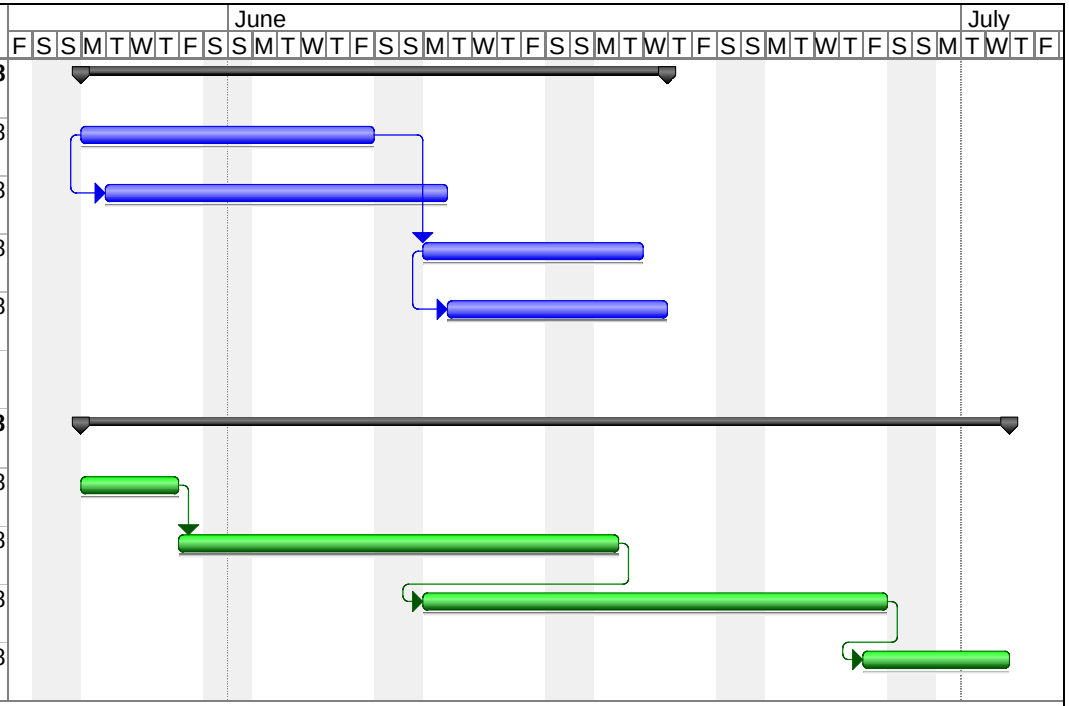
Appendix F: Green Roof Plant List

1. Sedum Kamtchaticum
2. Sedum spurium ‘Fuldaglut’
3. Sedum spurium ‘John Creech’
4. Sedum takesimense
5. Sedum spurium ‘White Form’
6. Sedum spurium ‘Eco Mt. Emei’
7. Delosperma nubigenum
8. Delosperma oberge
9. Delosperma cooperii
10. Delosperma 'Kelaidis'
11. Allium schoenoprasum
12. Talinum calycinum
13. Sedum Album ‘Murale’
14. Sedum Floriferum ‘W. Gold’
15. Sedum Reflexum
16. Dianthus firewitch

All plants to be provided by Saul Nurseries, Atlanta, Ga.

Appendix G: Green Roof Schedule

ID	Task Name	Duration	Start	Finish
1	**Original Roof**	**18 days**	**Mon 5/26/08**	**Wed 6/18/08**
2	Built Up Roof South	10 days	Mon 5/26/08	Fri 6/6/08
3	Roof Membrane South	10 days	Tue 5/27/08	Mon 6/9/08
4	Built Up Roof North	7 days	Mon 6/9/08	Tue 6/17/08
5	Roof Membrane North	7 days	Tue 6/10/08	Wed 6/18/08
6				
7	**Green Roof**	**28 days**	**Mon 5/26/08**	**Wed 7/2/08**
8	Vapor Barrier	4 days	Mon 5/26/08	Thu 5/29/08
9	Flashing	12 days	Fri 5/30/08	Mon 6/16/08
10	Garden Rooftop System	15 days	Mon 6/9/08	Fri 6/27/08
11	Pavers	4 days	Fri 6/27/08	Wed 7/2/08



Project: Green Roof Schedule
Date: Sat 4/4/09

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

Appendix H: Redesigned Concrete Calculations

$b_{original}$ = 12” $b_{redesign}$ = 16”

d = 28”-1.5”-0.375”- (0.875” / 2) = 25.7”

#7 bar = 0.6 in^2

f_y = 60 ksi

f'_c = 5,000 psi

Redesign

Moment

$a = (A_s * f_y) / (0.85 * f'_c * b)$

$a = (2.4\ in^2 * 60{,}000\ psi) / (0.85 * 5{,}000\ psi * 16”) = 2.118$ in

$M_n = (A_s * f_y) * (d - (a/2))$

$M_n = (2.4\ in^2 * 60{,}000\ psi) * (25.7” - (2.118”/2)) = 295.7$ ft.-kips

$\phi M_n = (0.9) * 295.7$ ft.-kips = 266.1 ft.-kips

$A_{s(min)} = (3 * b * d * \sqrt{f'_c}) / f_y = (3 * 16” * 25.7” * \sqrt{5{,}000\ psi}) / 60{,}000\ psi$

$A_{s(min)}$ = 1.45” (this one applies) 2.4” ≥ 1.45”

$A_{s(min)} = (b * d * 200) / f_y = (200 * 16” * 25.7”) / 60{,}000\ psi$

$A_{s(min)}$ = 1.03”

$c = a/\beta = 2.118/0.8 = 2.65$

$c_{max} = 0.375 * 25.7 = 9.64 \geq 2.65$ (Tension Controlled)

Shear

$V_c = 2 * b * d * \sqrt{f'_c} = 58.15$ kips

$V_s = n * A_v * f_y$

n = number of stirrups A_v = area of stirrups (#3 stirrup)

$V_s = 2 * (0.11\ in^2) * (60{,}000\ psi) = 13.2$ kips

$\Phi(V_c + V_s) = 0.75 * (58.15\ kips + 13.2\ kips) = 53.15$ kips

$b_{min} = 2 * (1.5”) + 2 * (0.375) + 4 * (0.875) + 3 * (1.27) = 11.06” \leq 16”$

Appendix I: Fifth Floor Roof Structural Member Take offs

Formwork:

Member	Qty.	Length (ft)	Total (ft)	Width (in)	Depth (in)	Factor	Revised Width	Added Width (in)	SFCA Increase
CB 65	4	36	144	12	22	1.33	16	4	48
CB 77	24	28	672	12	22	1.33	16	4	224
CB 77	11	26	286	12	22	1.33	16	4	95
CB 99	2	36	72	24	22	1.33	32	8	48
CB152	5	26	130	24	22	1.33	32	8	87
CB 155	5	28	140	24	22	1.33	32	8	93
CB 160	5	28	140	18	22	1.33	24	6	70
CB 165	4	28	112	24	22	1.33	32	8	75
PTB 76	1	52	52	42	22	1.33	56	14	61
PTB 78	1	52	52	18	22	1.33	24	6	26
PTB 80	1	36	36	30	22	1.33	40	10	30
PTB 85	3	36	108	30	22	1.33	40	10	90
PTB 88	1	82	82	30	22	1.33	40	10	68
PTB 100	6	70	420	33	22	1.33	44	11	385
			2446					Total =	1400
								10% waste	**1540**

Redesigned Concrete Takeoffs																
Member	Qty.	Length (ft)	Total (ft)	Width (in)	Depth (in)	Factor	Revised Width	Rebar	Qty.	Factor	Revised Rebar	Original CY	New CY	Increase	Original Tons	Revised Tons
CB 65	4	36	144	12	22	1.33	16	#8	3	2	6	10	13	3	0.5767	1.1534
CB 77	24	28	672	12	22	1.33	16	#7	2	2	4	46	61	15	1.3736	2.7471
CB 77	11	26	286	12	22	1.33	16	#7	2	2	4	19	26	6	0.5846	1.1692
CB 99	2	36	72	24	22	1.33	32	#9	4	2	8	10	13	3	0.4896	0.9792
CB152	5	26	130	24	22	1.33	32	#7	4	2	8	18	23	6	0.5314	1.0629
CB 155	5	28	140	24	22	1.33	32	#7	4	2	4	19	25	6	0.5723	1.1446
CB 160	5	28	140	18	22	1.33	24	#7	3	2	6	14	19	5	0.4292	0.8585
CB 165	4	28	112	24	22	1.33	32	#8	3	2	6	15	20	5	0.4486	0.8971
PTB 76	1	52	52	42	22	1.33	56	-	-	2	-	12	16	4	-	-
PTB 78	1	52	52	18	22	1.33	24	-	-	2	-	5	7	2	-	-
PTB 80	1	36	36	30	22	1.33	40	-	-	2	-	6	8	2	-	-
PTB 85	3	36	108	30	22	1.33	40	-	-	2	-	18	24	6	-	-
PTB 88	1	82	82	30	22	1.33	40	-	-	2	-	14	19	5	-	-
PTB 100	6	70	420	33	22	1.33	44	-	-	2	-	78	104	26	-	-
			2446											94	5.006	10.012
														98.8		**5.006**

Appendix J: Concrete Column Estimate

Item	*Labor*	*Material*	*Equipment*	*Total*
Drilled Pier Excavation	$ 26,827.20	$ -	$ 38,154.24	$ 64,981.44
Drilled Pier Concrete	$ 37,250.70	$ 357,738.00	$ 1,214.34	$ 396,203.04
Drilled Pier Rebar	$ 31,757.60	$ 92,876.00	$ 1,348.20	$ 125,981.80
Grade Beams Concrete	$ 1,147.98	$ 11,804.70	$ 969.29	$ 13,921.97
Grade Beams Rebar	$ 4,107.20	$ 8,909.00	$ 135.90	$ 13,152.10
Retaining Wall Forms	$ 95,035.15	$ 134,335.40	$ -	$ 229,370.55
Retaining Wall Conc.	$ 144,076.00	$ 867,640.00	$ 52,536.00	$ 1,064,252.00
Retaining Wall Rebar	$ 11,271.15	$ 32,085.00	$ 465.75	$ 43,821.90
SOG Forms	$ 1,900.80	$ 6,388.80	$ -	$ 8,289.60
SOG Concrete	$ 8,266.50	$ 53,955.00	$ 3,019.50	$ 65,241.00
SOG Rebar	$ 7,676.25	$ 10,132.65	$ -	$ 17,808.90
SOG Finish	$ 11,481.00	$ -	$ -	$ 11,481.00
Column Forms	**$ 55,527.57**	**$ 17,631.72**	**$ -**	**$ 73,159.29**
Column Concrete	**$ 10,626.70**	**$ 57,429.40**	**$ 3,888.92**	**$ 71,945.02**
Column Rebar	**$ 14,973.00**	**$ 37,432.50**	**$ -**	**$ 52,405.50**
Elev. Slab Forms	$ 245,540.88	$ 108,391.92	$ -	$ 353,932.80
Elev. Beam Forms	$ 304,963.15	$ 69,795.69	$ -	$ 374,758.84
Elev. Slab Concrete	$ 47,368.00	$ 339,216.00	$ 17,266.40	$ 403,850.40
Elev. Slab Rebar	$ 22,579.20	$ 71,424.00	$ -	$ 94,003.20
Elev. Beam Rebar	$ 18,562.80	$ 46,407.00	$ -	$ 64,969.80
Elev. Slab Finish	$ 51,299.00	$ -	$ -	$ 51,299.00
Structural Steel W	$ 17,236.85	$ 301,498.80	$ 12,328.73	$ 331,064.38
Structural Steel C	$ 13,996.80	$ 4,561.92	$ 1,736.64	$ 20,295.36
Decking	$ 2,485.36	$ 16,181.28	$ 264.40	$ 18,931.04
PT Allowance	$ 20,000.00	$ 50,000.00	$ 10,000.00	$ 80,000.00
Total	**$ 1,205,956.84**	**$ 2,695,834.78**	**$ 143,328.31**	**$ 4,045,119.93**

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