Correlation Between Attentiveness and Natural Light in a Library

A Major Qualifying Project Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE

in Partial Fulfilment of the Requirements for the degree of Bachelor of Science

By

Dominick Timpanaro

Fangyi Liu

Report Submitted To:

Professor Leonard Albano

Professor Soroush Farzin

Abstract: The conditions someone is in can affect the quality of work that they do. This project investigates whether there is a correlation between different amounts of natural light in a room and the attentiveness of a person in that room. We designed a Library to test for this correlation due to the number of different spaces a library can have. The design work covered the interior layout, structural design and exterior site layout. With this knowledge, new considerations can be made when designing work and study spaces So that these spaces can help people work more efficiently.

Authorship: Dominick Timpanaro worked on the paper, case studies, site analysis, traffic study, conceptual designs, architectural design, landscape, code research, interior design, structural design, and Revit model. Fangyi Liu worked on the Revit model and the structural design of the building.

Acknowledgements: We would like to acknowledge and thank Professor Leonard Albano and Professor Soroush Farzin for their support and contributions to our research. As well as Karen Coghlan for their help with citations and sources on the paper.

Capstone Design Statement: Worcester Polytechnic Institute requires its students to complete a Capstone Design Requirement for their major. It requires the students to highlight what they have learned from their major. The work on this project is the work needed to fulfil the Architectural Engineering Capstone Design Requirement. The software programs Autodesk Revit, Microsoft Word and Microsoft Excel were used for the design and organization of the architectural design of the project. The structural work was done using loads from the IBC and strength values for structural steel from the AISC *Manual of Steel Construction, 15th edition*.

Table of Contents

Abstract

Authorship

Acknowledgements

Capstone Design Statement

Table of Contents

List of Figures

List of Tables

1: Introduction

2: Background

- **2.1: Attentiveness**
- **2.2: Literature Review of the Effects of Natural Light on Building Occupants**

3: Architectural Design

- **3.1: Introduction**
- **3.2: Case studies**
  - **3.2.1: Clifton Park Public Library**
  - **3.2.2: Central Library in Copley Square**
  - **3.2.3: Geisel Library**
  - **3.2.4: Stuttgart City Library**
  - **3.2.5: Summary of Case Studies**

3.3: Site Analysis

3.3.1: Classification

3.3.2: Parking Spots and Set Back

3.3.3: Traffic

3.3.4: Transportation and The Surrounding Area

3.4: Floor Plans

3.5: Landscape

4: Structural Design

4.1: Introduction

4.2: Layout

4.3: Calculations and Member Sizes

5: Citations

Appendix A - Preliminary Floor Plan Sketches

Appendix B – Preliminary Tech Suite and Conference Room Sketches

List of Figures:

Figure 1: Exterior Front View of The Clifton Park Public Library
Figure 2: Interior view of the Clifton Park Public Library

Figure 3: Floor Plans For Central Library

Figure 4: Floor Plans For Central Library

Figure 5: Exterior View of Geisel Library

Figure 6: Section View of Geisel Library

Figure 7: Exterior View of The Stuttgart City Library

Figure 8: Interior View of the Stuttgart City Library

Figure 9: A Map for Zoning, The Blue dot shows the location of the site.

Figure 10: Key for Zoning Distinctions Map

Figure 11: Google Maps Screen Shot With annotations

Figure 12: Table 4.4 from worcesterma.gov

Figure 13: ADA Handicap Parking Spot Guide

Figure 14: Traffic Ratings and Explanation

Figure 15: Screenshot of Google Maps Showing the Sidewalks and Bus Stops

Figure 16: 1st Floor Floor Plan

Figure 17: 1st Floor View 1

Figure 18: 1st Floor View 2

Figure 19: 2nd Floor Floor Plan

Figure 20: 2nd Floor View 1

Figure 21: 2nd Floor View 2

Figure 22: 3rd Floor Floor Plan

Figure 23: 3rd Floor View 1

Figure 24: 3rd Floor View 2

Figure 25: Tech Suite

Figure 26: Conference Room

Figure 27: Exterior Rendering of the Library and Site.

Figure 28: Diagram That Goes with the Beam and Girder Calculations

Figure 29: AISC 15th edition, Table 6-2 W16

Figure 30: AISC 15th edition, Table 6-2 W18

Figure 31: AISC 15th edition, Table 4-1a W12

List of Tables:

Table 1: Load Calculations

Table 2: Beam and Girder Load Calculations

Chapter 1: Introduction:

Finding a place to get work done is a struggle for some students. For some people the environment around them can cause them to lose focus on the task or tasks they are trying to accomplish. There are many factors that can lead to a space not being suitable for a person, but these factors vary from person to person. We look to see how natural light plays a part in making a space a “good” or “bad” influence on a person's attentiveness.

According to Edwards, L, & Torcellini,

A Daystar article, “Benefits of Natural Daylighting” (1998), states that there is increased student and teacher attendance, increased achievement rates, reduced fatigue factors, improved student health, and enhancement of general development. Furthermore, natural lighting eliminates noise and flickering from electric light sources and provides the best quality of light available in classrooms, gymnasiums, and corridors. Other research has shown that students in windowless classrooms are more hostile, hesitant, and maladjusted. Also, students in windowless classrooms tend to be less interested in their work and complain more. (Edwards, L, & Torcellini, p17)

This project focuses on how natural light can affect a person's attentiveness when trying to get work done. A library was designed to investigate this research, which made the most sense due to a library having various rooms with various purposes/uses. With the knowledge found here we look to see how study/workspaces can be made so that students and other people can work at their most efficient levels.

Chapter 2: Background:

2.1: Attentiveness: According to the dictionary provided by the APA (American Psychological Association) attentiveness is described in the following two ways: the state of being alert and actively paying attention, and the quality of actively attending to the needs of others. Factors that can influence someone's attention are described as external and internal. Examples of external factors are the size and intensity of a stimuli, the color or contrast of a stimuli, and the emotional burden caused by a stimuli. Internal factors are how interested a person is in a stimuli, any emotions they have towards a stimuli, effort required by the task, a person's organic state and their train of thought.

2.2: Literature Review of the Effects of Natural Light on Building Occupants:

The Authors of this review go over data and knowledge that covers many aspects of natural light and occupants. Throughout the review the type of occupants mentioned change (I.e. factory workers and students). The excerpts that follow provided insight into a vast range of things to consider when dealing with natural light in our building space.

This excerpt talks about the color of the light and how daylight compares to other sources of light.

Daylight provides a better lighting environment than cool white or energy-efficient fluorescent electrical light sources because “daylight…most closely matches the visual response that, through evolution, humans have come to compare with all other light” (Franta and Anstead 1994). The majority of humans prefer a daylit environment because sunlight consists of a balanced spectrum of color, with its energy peaking slightly in the blue-green area of the visible spectrum (Liberman 1991) (Edwards, L, & Torcellini, p3)

According to Edwards, L, & Torcellini, A person's psychological state can be affected by daylight.

Humans are affected both psychologically and physiologically by the different spectrums provided by the various types of light. These effects are the less quantifiable and easily

overlooked benefits of daylighting. Daylighting has been associated with improved mood, enhanced morale, lower fatigue, and reduced eyestrain. One of the important psychological aspects of daylighting is meeting a need for contact with the outside living environment (Robbins 1986).

Those are just two examples of how light can affect a person; other examples would include glare from the light, lack of light and intensity of the light.

Chapter 3: Architectual Design:

3.1: Introduction: With the idea of making spaces that we could test to for the correlation between natural lighting and attentiveness, a library made the most sense. This is seen in the following case studies. Due to the fact that libraries come in many shapes, sizes and uses, the idea when making the building was to have different spaces unique to their own purpose.

3.2: Case studies: Four libraries were researched to prepare to design the library. The libraries were selected for their use of natural light and the area around them, their interior layouts, and their exterior layout.

3.2.1: Clifton Park Public Library: 475 Moe Rd, Clifton Park, NY 12065

Located in Upstate New York, this library was chosen for its use of different sized windows. The building flows with light from the assortment of windows throughout the multi-floor space. The floor layout was also looked on for inspiration, due to the flow from the first to second floor. The second-floor features spaces for cooperative work, solo work, meeting spaces and has a large area for children. This children's area consists of their collection of children's books, as well as areas that a child could find comfortable to read, and computers loaded with educational games.

Figure 1: Exterior Front View of The Clifton Park Public Library, Picture from WCGS

Figure 2: Interior view of the Clifton Park Public Library, "Clifton Park Halfmoon Public Library" by David Lee King is marked with CC BY-NC-SA 2.0.

3.2.2: Central Library in Copley Square: 700 Boylston Street, Boston, MA 02116

This library was chosen for inspiration due to its floor layout. The library features many types of unique spaces, such as offices, reading spaces, café spaces, research rooms, and meeting rooms. For inspiration and guidance in this project's design, the floor layout of the Central Library was looked at. Specifically looking at the layout of the different sections of literature all in the same room.

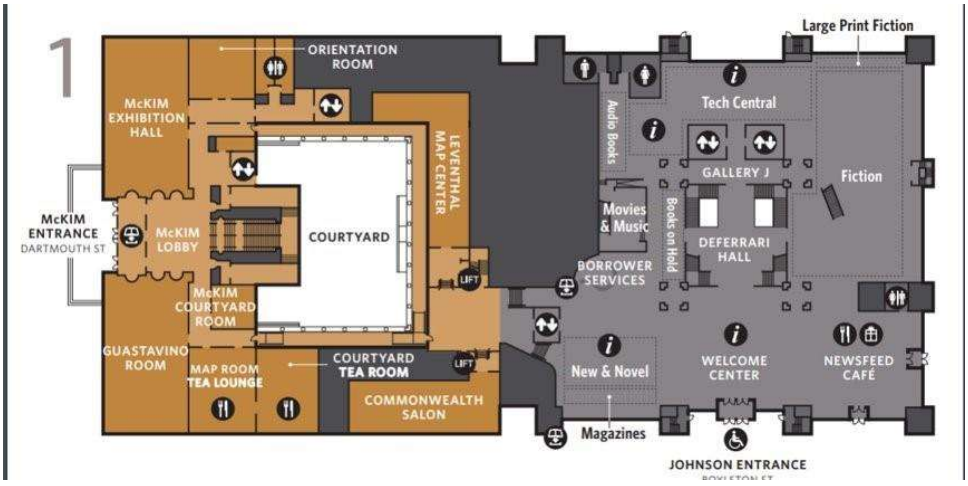


Figure 3: Floor Plans for Central Library

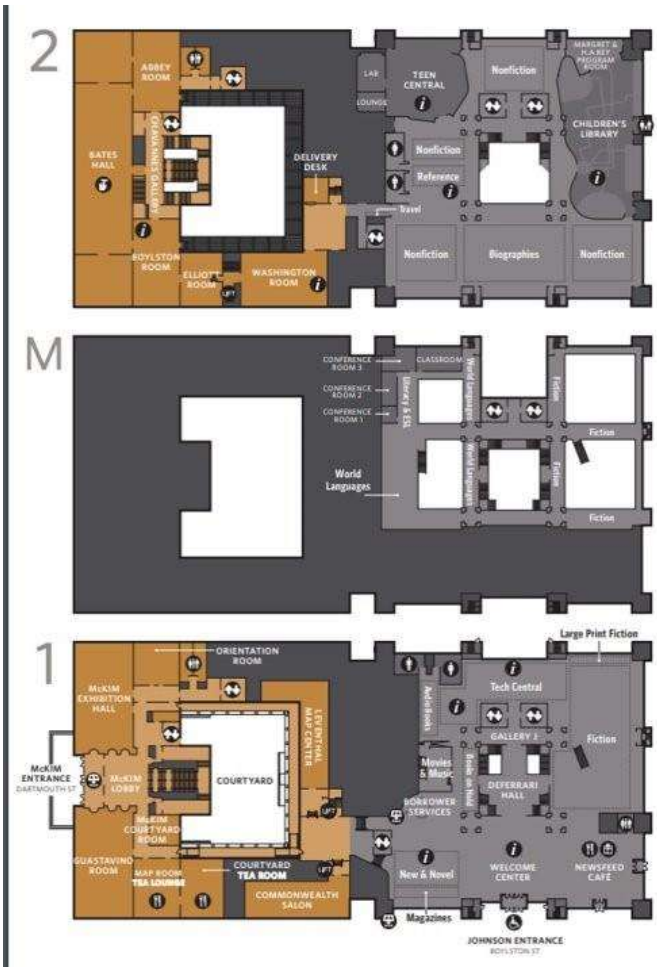


Figure 4: Floor Plans for Central Library

3.2.3: Geisel Library: 9500 Gilman Dr, San Diego, CA 92093

This is the main library building for the University of California, San Diego designed by William Pereira It opened in 1970 and had renovations done in 1993. The library was constructed in a way that its arches and other features resemble hands holding a stack of books. The initial design was made with the intention of renovating the space, which was done in 1993. This was researched to be used as an example of a reinforced concrete structure. The interior layout was also investigated for guidance of this project's design. The library also features landscaping known as The Snake Path, a path that winds through an assortment of gardens.

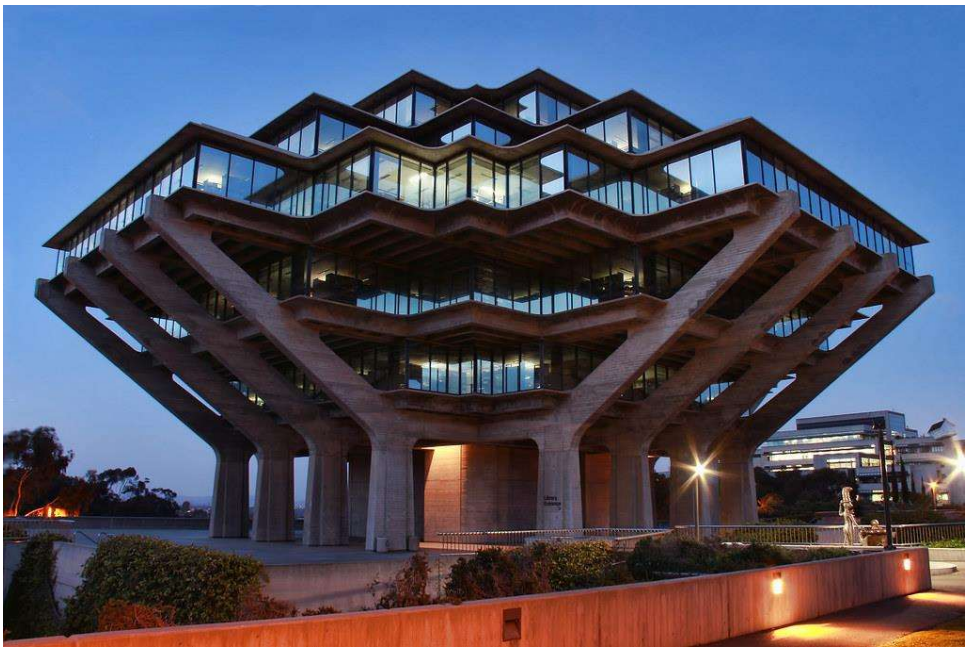


Figure 5: Exterior View "Night View of The Geisel Library, University of California San Diego" by o palsson is marked with CC BY 2.0.

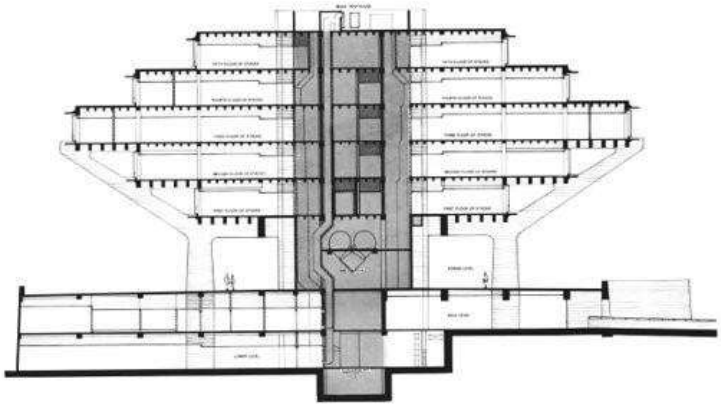


Figure 6: Section View of Geisel Library, ArchDaily

3.2.4: Stuttgart City Library: Stuttgart, Germany: Mailaender Platz 1 · 70173 Stuttgart

The Stuttgart City Library is a large square building with a block façade around its exterior shell. The central aspect of the library, called the heart, is where the library space truly is. The interior is based off the Pantheon. The space is open in every direction on the inside and features a multi-floor gallery space. The books are located on the exterior of the heart area, which is an interesting way to organize the space and was considered during the design of this project.

Figure 7: Exterior View of The Stuttgart City Library, "Cube" by timtom.ch is marked with CC BY-NC-SA 2.0.

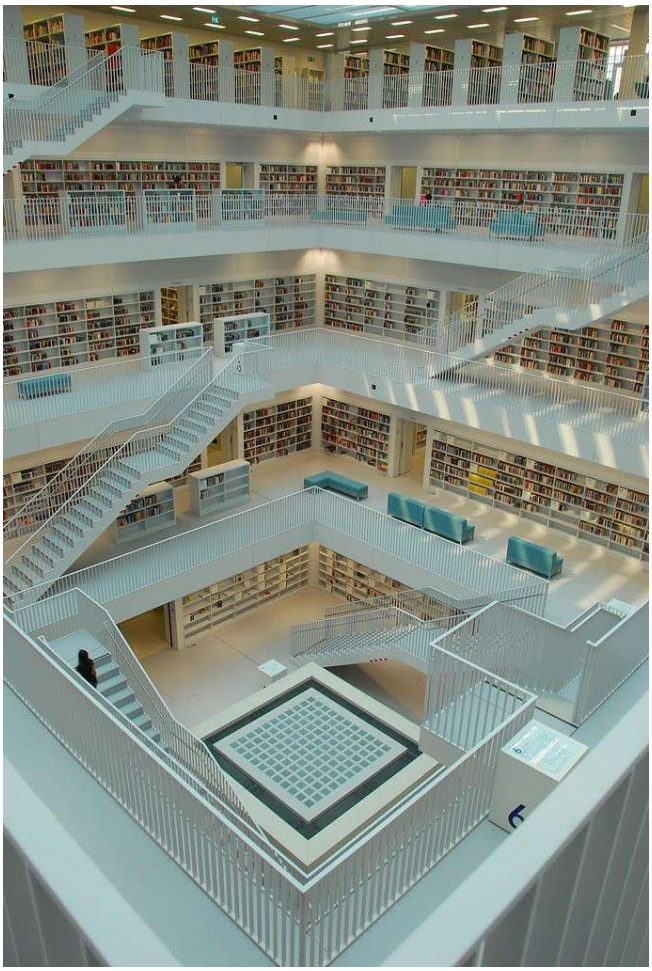


Figure 8: Interior View of the Stuttgart City Library, "Stuttgart Library Interior" by bobarcpics is marked with CC BY 2.0.

3.2.5: Summary of Case Studies: The libraries mentioned were researched to give ideas on how to design the library. These designs varied from one another, setting the table to make the library in a way that fits with the surrounding community.

3.3 Site Analysis

3.3.1: Classification: The site is located at 101 Highland Street, Worcester, MA 01609. It was chosen due to its access to Highland Street, large local community of residents and students, and for its access to public transportation. According to Worcester's website for zoning, this plot of land falls under the distinction of BL1 which allows libraries. Worcester is in Massachusetts, in the Northeast of the United States, where it can rain and or snow depending on the time of the year.

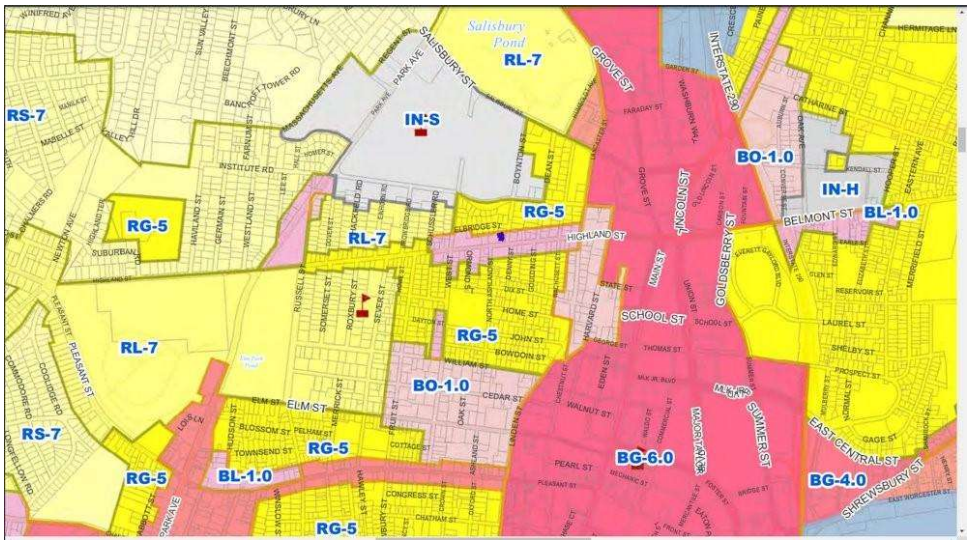


Figure 9: A Map for Zoning, The Blue dot shows the location of the site, Zoning ordinance & map | city of worcester, ma. (n.d.)

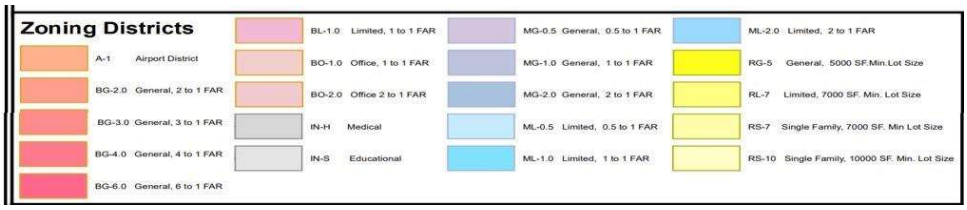


Figure 10: Key for Zoning Distinctions Map, Zoning ordinance & map | city of worcester, ma. (n.d.)

3.3.2: Parking Spots and Set Back: Due to this distinction and the zoning laws of the area, the maximum floor area is restricted to 15,000 square feet. According to the same source, the overall setbacks required for the site are 10 feet to the sides of the lot and 20 feet for the rear. The metric used for determining the required amount of parking was one spot for every 350sq ft of floor space; using that ratio resulted in 29-31 regular spaces and 2 accessible spaces.

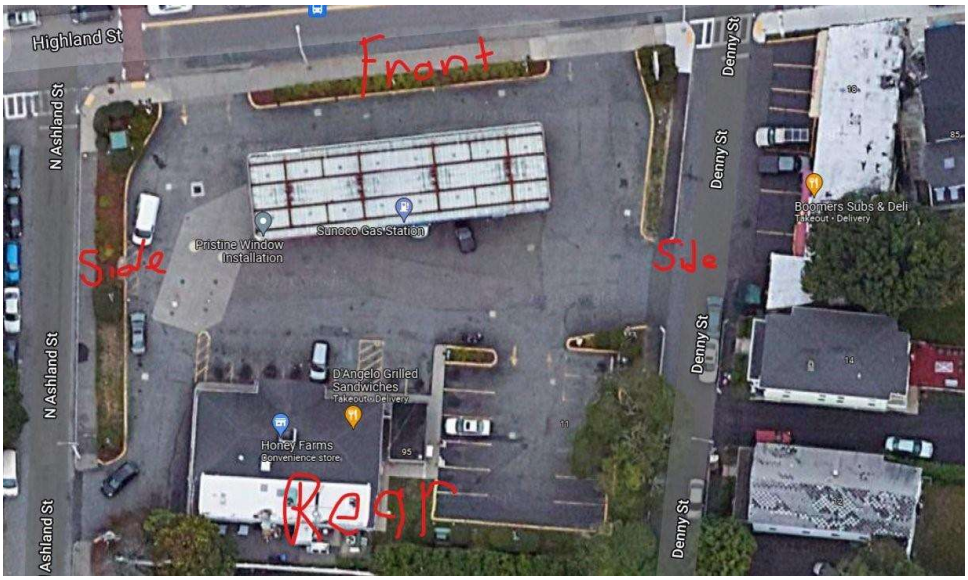


Figure 11: Google Maps Screen Shot With annotations

TABLE 4.4 - OFF-STREET ACESSORY PARKING REQUIREMENTS

USE	PRIMARY SPACES	
RESIDENTIAL	**Number per Measurement Unit**	
Single, two or three family dwelling	2	Dwelling unit
Multi-family dwelling	2	Dwelling unit
Group Residence	0.25	Bed
Lodging House	0.5	Bed
Housing for elderly (subsidized)	1	Dwelling unit
Dormitory	0.33	Dwelling unit
Continuing Care Retirement Community	1	Dwelling unit
CCRC Associated Medical Facilities	0.5	Bed
Temporary Shelter	0.1	Bed
All other Residential, including Hotel & Motel	1	Bedroom
Limited Residential Hospice House	0.5	Per bed, plus (1) per employee living on the premises
GENERAL	**Number per Measurement Unit**	
Nursing, Convalescent Home/Facility	0.33	Bed
Hospital		
In-Patient	1	Bed
Out-patient	3	Treatment room/space
Clinic	4	Treatment room/space
Educational Institution	10	Classroom, plus residential above
Places of Assembly (non-profit or profit)	0.25	Person accommodated
Day care center/Adult Day Care Center	1	Teacher or staff person
Library, museum, recreation/service facility	1	350 sf. Gross floor area
Club, lodge, other (non-profit and profit)	2.5	350 sf. Gross floor area
Health club (profit)	1	350 sf. Gross floor area
Heliport	1	350 sf. Gross floor area

Figure 12: Table 4.4, Building & zoning | city of Worcester, ma. (n.d.)

Combining the More Stringent Regulations of the Americans with Disabilities Act and the Massachusetts Architectural Access Board

All parking lots for customers or visitors (with the exception of valet parking), should have accessible spaces for vehicles with proper identification. Parking lots for employees (built or altered as of 1/26/92) must also have accessible spaces. If an employee with a disability needs such accommodation in an older parking lot, s/he should request it of the employer.

Parking Space Size:
Accessible spaces should be at least 8 feet wide, with level access aisles not less than 5 feet wide. Two accessible spaces may share a common aisle.

Location:
These spaces should be in a level location providing the shortest safe, accessible route of travel to an accessible entrance. With more than one accessible entrance, the spaces should be located near each accessible entrance. Sidewalks at such spaces should have curb cuts at each access aisle, so a person is not required to enter the stream of traffic to get to a sidewalk.

Parking Space Number:

Total Spaces	Required Accessible Spaces (521 CMR and ADA)
1-4 (ADA Only)	1 spaces without signage
5-14 (ADA Only)	1 space
15-25	1 space
26-50	2 spaces
51-75	3 spaces
76-100	4 spaces
101-150	5 spaces
151-200	6 spaces
201-300	7 spaces
301-400	8 spaces
401-500	9 spaces
501-1000	2% of total
1001 and Over	20, plus 1 for each 100, or fraction thereof, over 1000

Figure 13: ADA Handicap Parking Spot Guide, mass.gov

3.3.3: Traffic: Traffic in the area is not bad for a city, and the noise level in the area goes up typically when the number of vehicles on the road increases. But the noise of traffic is not too distracting or loud for those in the building. The scale used in the accompanying figure was derived from Google's traffic option on Google Maps -- there are four colors representing four levels of traffic. The scale takes these colors and converts them into numbers.

Traffic Patterns

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
9am	1	2	2	2	2	2	1
12pm	2	2	2	2	2	2	2
3pm	2	1.5	2	2	2	2	2
6pm	2	2	2	2	2	2	2

Rank	Meaning (fast meaning less traffic
1	fast
2	Kinda fast
3	Kinda slow
4	Slowest

Figure 14: Traffic Ratings and Explanation

3.3.4: Transportation and The Surrounding Area: This location is right in the middle of a few schools and colleges, giving people in the surrounding area a place to do work. There are numerous bus stops on Highland Street, and sidewalks all around the area. There is not much space for off-street parking.

Figure 15: Screenshot of Google Maps Showing the Sidewalks and Bus Stops

3.4: Floor Plans

The preliminary concepts for the floor plans were all sketched by hand and can be found in Appendix A. We took a screen shot of the floor layout and added it to a PowerPoint presentation, there were three identical slides containing an open layout of the building. The PowerPoint was then printed to fit all the slides on one piece of paper and printed

The first floor was designed to house many the library's books, a café-like space and rooms/storage for library staff. It is also home to a computer area with a number of computers to be used by those visiting the library. The checkout area has an exterior window slot for people returning books. The blue dots represent the location of columns. The interior column spacing was set to balance the desire for flexibility with economical girder sizes for resisting gravity loads.

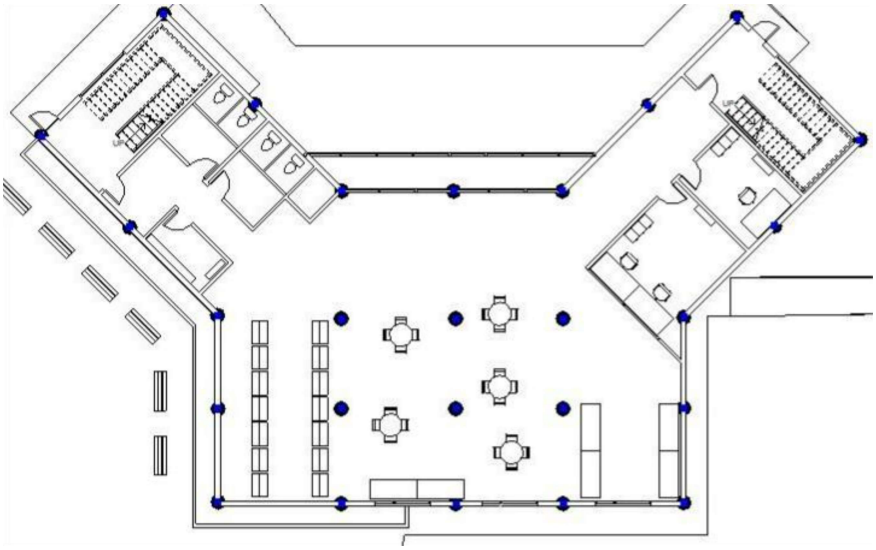


Figure 16: 1st Floor Floor Plan

Figure 17: 1st Floor View 1

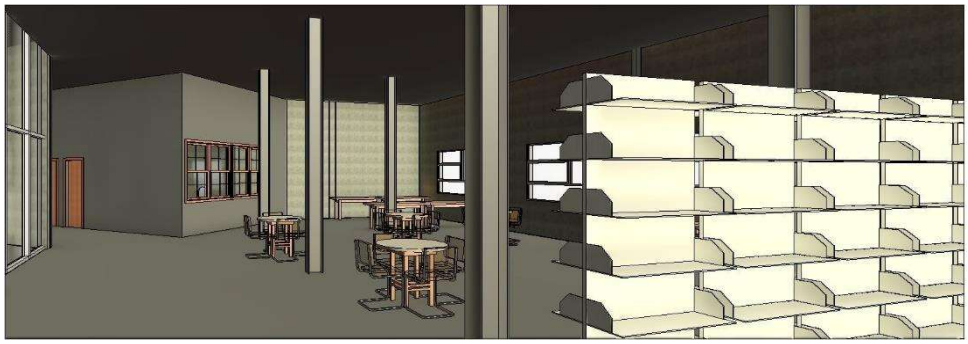


Figure 18: 1st Floor View 2

The second floor features more bookshelves and spaces for people to read and or do other activities. One of these areas will house a large semi-circular couch. Following the outline of the couch there is a table with stools for people to work on. Scattered around the area there will be different forms of seating that can be moved around to fit the needs of the space.

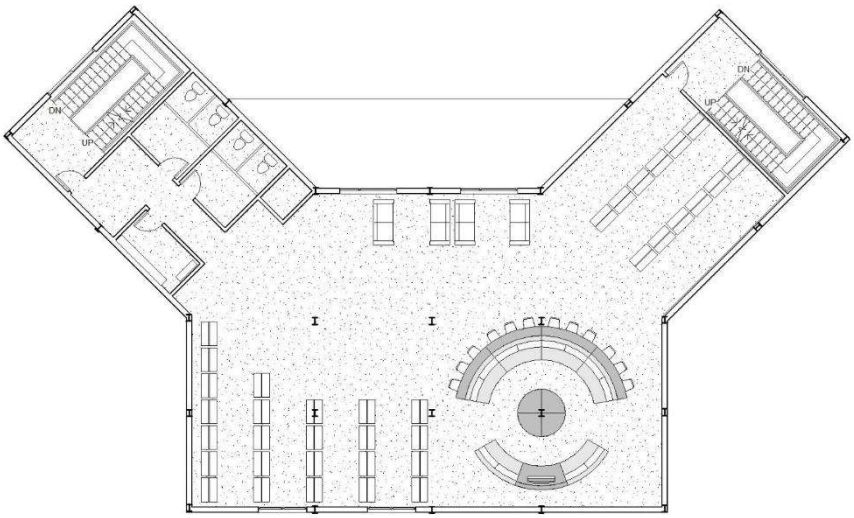


Figure 19: 2nd Floor Floor Plan

Figure 20: 2nd Floor View 1

Figure 21: 2nd Floor View 2

The third floor is the working floor where people come to do work; it features several tech suites designed for four people, as well as two large conference rooms. These rooms were set up to allow the users to control the space, allowing them to control how much natural light is let in. See Appendix B for preliminary sketches of the Tech suite and conference rooms. There are also tables set up to allow a more casual place to work as well as cubby spaces for people to complete their individual work.

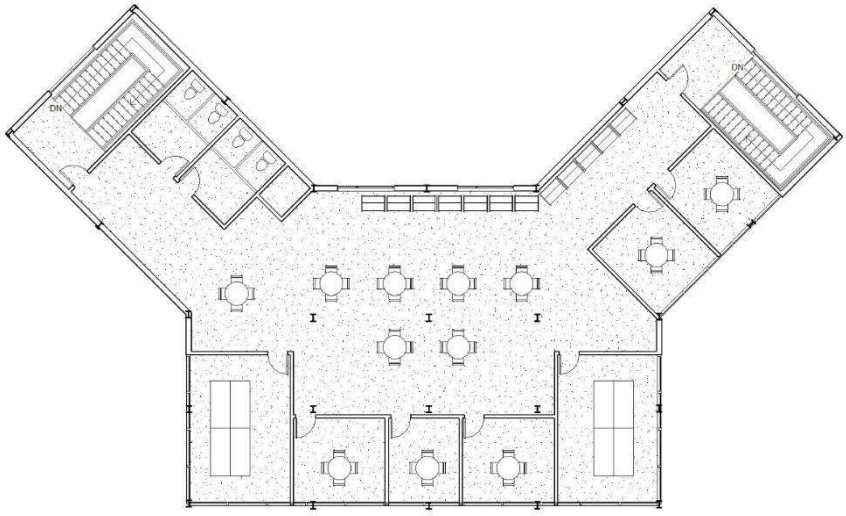


Figure 22: 3rd Floor Floor Plan

Figure 23: 3rd Floor View 1

Figure 24: 3rd Floor View 2

Figure 25: Tech Suite

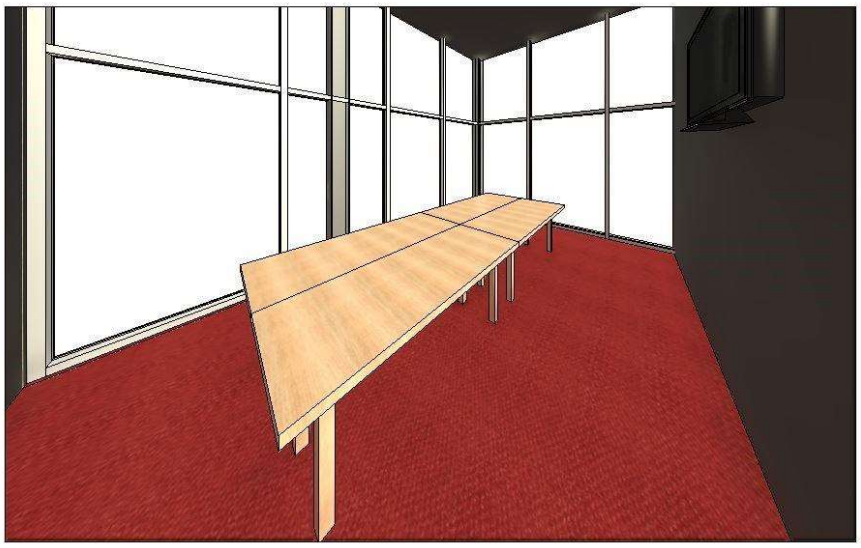


Figure 26: Conference Room

3.5: Landscape:

When the weather is nice there is an area outside the library for people to gather and use. The landscape features flower boxes around the building, a walking path, park style benches, picnic tables, and a pond. This area will be surrounded by a line of bushes forming a wall that blocks the space from the sidewalk and the road. Putting life in the pond would depend on how storm water runs off in the area. The green rectangle is the area where the pond would go; the true shape of the pond would be left up to a skilled pond builder.

Figure 27: Exterior Rendering of the Library and Site.

Chapter 4: Structural Design

4.1: Introduction: The structure of the building must take into consideration that the building will be home to people and books, so it must be able to handle both at once. Due to the location of the site, the local building code also requires the consideration of snow loads.

4.2: Layout: We first had to choose how each floor was going to be supported. The first-floor level relies on a slab on grade to support the dead and live loads. The second-floor level relies on a grid of beams and girders to support a concrete slab on a metal deck. See Fig 28 below for the layout of the supporting beams and girders on the second floor (the numbers pertain to the calculations and numbers located in Table 2). Blue, yellow and green lines represent beams while red lines represent girders. This layout worked the best for the design which is why we chose it. Table 1 has the load calculations that we did to find the value we were going to use in our calculations located on Table 2. Table 2 has calculations of loads and moments over the different spans of girders and beams.

4.3: Calculations and Member Sizes: After designing a few conceptual layouts, we decided to go with the one we chose due to the spacing working the best for the floor layout and for the flow of the building. We used a spreadsheet to organize our data and run the calculations.

After calculating the loads, the AISC *Steel Construction Manual, 15th edition* was used to determine the required size of the structural steel beams, girders, and columns based on the philosophy of Load and Resistance Factor Design (LRFD). When selecting the member sizes, a decision had to be made between having a large number of different sized members or specifying sizes that worked for most situations, which would promote consistency throughout the systems. We decided to limit the number of different sized members throughout the system.

The beam size chosen was **W16x89**, and this member size will support all loads for any span beam span (Figure 29). The girder sizes are **W18x130**, and this member size will support the loads put on the girders for all spans in the building (Figure 30).

We used AISC 15th edition for the column sizing. Based on the building being Forty-five feet tall and the loads throughout the building we decided to go with **W12x87** for our columns, providing the necessary support for the floors and roof of the building (Figure 31).

Table 1: Load Calculations

	A	B	C	D	E	F	G	H	I	J	K
1	Floor	Load (psf)		Deck load							
2	DL	75		16							
3	LL	150									
4	Roof										
5	DL	75									
6	LL	20									
7	S	50									
8											
9	Column						Beams & Girders				
10	Load combination: 1.2D+1.6L+0.5S						Load Combination				
11	1.2(75+75+75)+1.6(150+150)+0.5*50 =	775	psf				Floor	1.2D+1.6L	1.2(75)+1.6(150) =	330	psf
12							Roof	1.2D+1.6S	1.2(75)+1.6(50) =	170	psf
13											
14	Area(ft2)	load(lb)	kips								
15	48	37200	37.2								
16	90	69750	69.75								
17	84	65100	65.1								
18	96	74400	74.4								
19	180	139500	139.5								
20	168	130200	130.2								
21	209	161975	161.975								
22	221	171275	171.275								
23	196	151900	151.9								
24	223	172825	172.825								
25	112	86800	86.8								
26	184	142600	142.6								
27	92	71300	71.3								

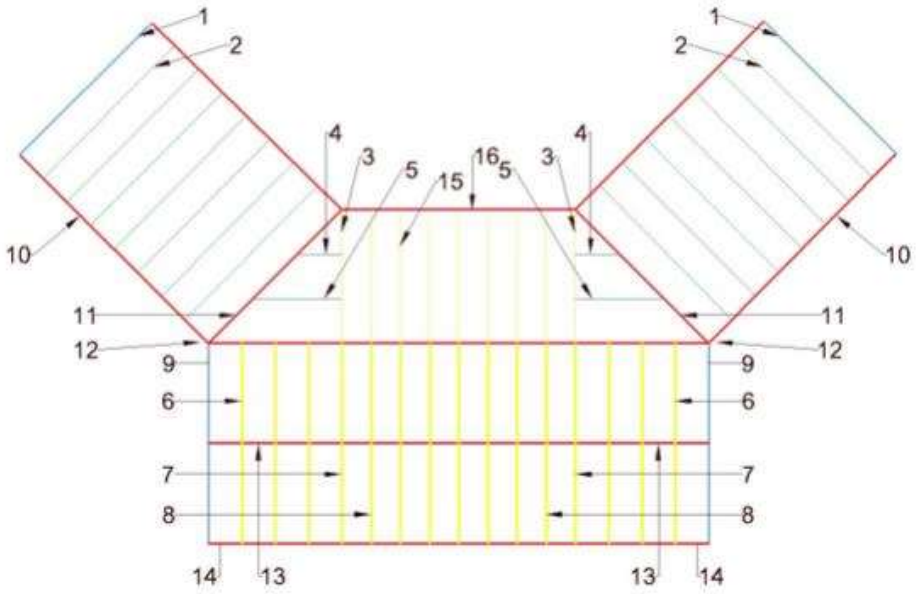


Figure 28: Location and Numerical Identification of Beams and Girders

Table 6-2 (continued)
Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces
W-Shapes

W16

F_y = 50 ksi
F_u = 65 ksi

W16×						Shape		W16×					
89		77		67[c]		lb/ft		89		77		67	
P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	Design		M_{nx}/Ω_b	$\phi_b M_{nx}$	M_{nx}/Ω_b	$\phi_b M_{nx}$	M_{nx}/Ω_b	$\phi_b M_{nx}$
Available Compressive Strength, kips								Available Flexural Strength, kip-ft					
ASD	LRFD	ASD	LRFD	ASD	LRFD			ASD	LRFD	ASD	LRFD	ASD	LRFD
784	1180	677	1020	587	882	Effective length, L_c, ft, with respect to least radius of gyration, r_y, or unbraced length, L_b, ft, for X-X axis bending	0	437	656	374	563	324	488
738	1110	636	956	551	828		6	437	656	374	563	324	488
722	1080	622	935	539	810		7	437	656	374	563	324	488
704	1060	606	911	525	789		8	437	656	374	563	324	488
684	1030	588	884	510	766		9	435	654	372	559	322	484
662	995	569	856	493	741		10	427	642	365	548	315	474
639	960	549	825	475	715		11	420	631	358	537	308	464
614	923	528	793	457	687		12	412	619	350	526	301	453
589	885	505	760	437	657		13	404	607	343	515	295	443
562	845	482	725	417	627		14	396	596	336	504	288	432
535	805	459	690	397	596		15	388	584	328	493	281	422
508	763	435	654	376	565		16	381	572	321	482	274	412
480	722	411	618	355	533		17	373	560	314	471	267	401
452	680	387	581	334	502		18	365	548	306	460	260	391
425	639	363	545	313	471		19	357	537	299	449	253	380
398	598	339	510	293	440		20	350	525	292	438	246	370
345	518	293	441	253	380		22	334	502	277	416	232	349
294	442	250	376	215	323		24	319	479	262	394	219	328
251	377	213	320	183	275		26	303	455	248	372	205	308
216	325	184	276	158	237		28	287	432	232	349	184	277
188	283	160	240	138	207		30	272	409	212	318	167	252
166	249	141	211	121	182		32	251	377	194	292	153	230
147	220	124	187	107	161		34	233	350	180	270	141	213
131	197	111	167	95.5	144		36	217	327	167	252	131	197
117	176	99.7	150	85.7	129		38	204	306	157	235	122	184
106	159	89.9	135	77.4	116		40	192	288	147	221	115	172
							42	181	272	139	209	108	162
							44	172	258	131	197	102	153
							46	163	245	125	187	96.7	145
							48	156	234	119	178	91.9	138
							50	149	223	113	170	87.5	132

Properties

Available Strength in Tensile Yielding, kips						Limiting Unbraced Lengths, ft					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	L_p	L_r	L_p	L_r	L_p	L_r
784	1180	677	1020	587	882	8.80	30.2	8.72	27.8	8.69	26.1
Available Strength in Tensile Rupture ($A_e = 0.75A_g$), kips						Area, in.^{2}					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	26.2		22.6		19.6	
640	960	553	829	478	717	Moment of Inertia, in.^{4}					
Available Strength in Shear, kips						I_x	I_y	I_x	I_y	I_x	I_y
V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$	1300	163	1110	138	954	119
176	265	150	225	129	193	r_y, in.					
Available Strength in Flexure about Y-Y Axis, kip-ft						2.49		2.47		2.46	
M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$	r_x/r_y					
120	180	103	154	88.6	133	2.83		2.83		2.83	

[c] Shape is slender for compression with F_y = 50 ksi.
Note: Heavy line indicates L_c/r equal to or greater than 200.

Figure 29: AISC 15th edition, Table 6-2 W16

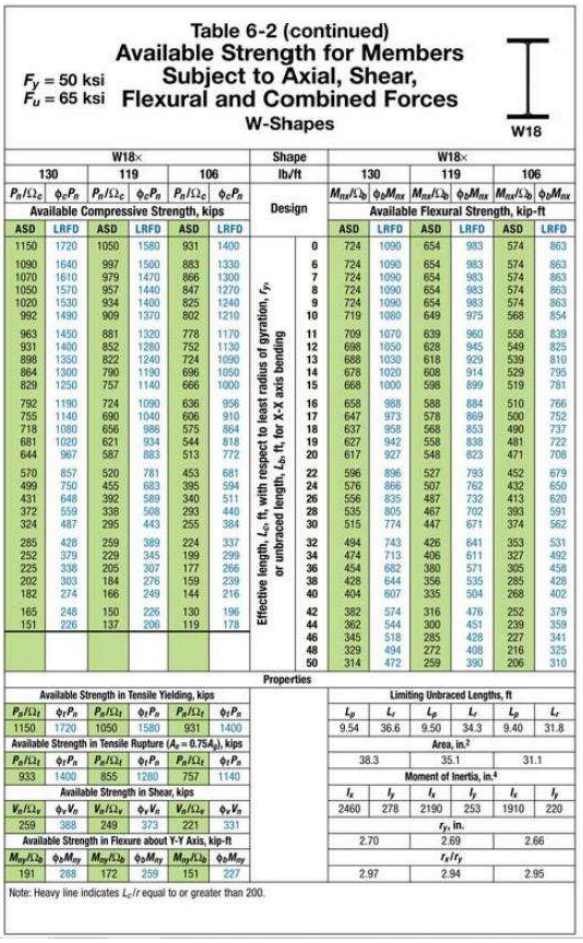


Table 6-2 (continued)
Available Strength for Members Subject to Axial, Shear, Flexural and Combined Forces
W-Shapes

F_y = 50 ksi
F_u = 65 ksi

W18

W18×						Shape	W18×					
130		119		106		lb/ft	130		119		106	
P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	Design	M_{nx}/Ω_b	$\phi_b M_{nx}$	M_{nx}/Ω_b	$\phi_b M_{nx}$	M_{nx}/Ω_b	$\phi_b M_{nx}$
Available Compressive Strength, kips							Available Flexural Strength, kip-ft					
ASD	LRFD	ASD	LRFD	ASD	LRFD		ASD	LRFD	ASD	LRFD	ASD	LRFD
1150	1720	1050	1580	931	1400	0	724	1090	654	983	574	863
1090	1640	997	1500	883	1330	6	724	1090	654	983	574	863
1070	1610	979	1470	866	1300	7	724	1090	654	983	574	863
1050	1570	957	1440	847	1270	8	724	1090	654	983	574	863
1020	1530	934	1400	825	1240	9	724	1090	654	983	574	863
992	1490	909	1370	802	1210	10	719	1080	649	975	568	854
963	1450	881	1320	778	1170	11	709	1070	639	960	558	839
931	1400	852	1280	752	1130	12	698	1050	628	945	549	825
898	1350	822	1240	724	1090	13	688	1030	618	929	539	810
864	1300	790	1190	696	1050	14	678	1020	608	914	529	795
829	1250	757	1140	666	1000	15	668	1000	598	899	519	781
792	1190	724	1090	636	956	16	658	988	588	884	510	766
755	1140	690	1040	606	910	17	647	973	578	869	500	752
718	1080	656	986	575	864	18	637	958	568	853	490	737
681	1020	621	934	544	818	19	627	942	558	838	481	722
644	967	587	883	513	772	20	617	927	548	823	471	708
570	857	520	781	453	681	22	596	896	527	793	452	679
499	750	455	683	395	594	24	576	866	507	762	432	650
431	648	392	589	340	511	26	556	835	487	732	413	620
372	559	338	508	293	440	28	535	805	467	702	393	591
324	487	295	443	255	384	30	515	774	447	671	374	562
285	428	259	389	224	337	32	494	743	426	641	353	531
252	379	229	345	199	299	34	474	713	406	611	327	492
225	338	205	307	177	266	36	454	682	380	571	305	458
202	303	184	276	159	239	38	428	644	356	535	285	428
182	274	166	249	144	216	40	404	607	335	504	268	402
165	248	150	226	130	196	42	382	574	316	476	252	379
151	226	137	206	119	178	44	362	544	300	451	239	359
						46	345	518	285	428	227	341
						48	329	494	272	408	216	325
						50	314	472	259	390	206	310

Effective length, L_c, ft, with respect to least radius of gyration, r_y, or unbraced length, L_b, ft, for X-X axis bending

Properties												
Available Strength in Tensile Yielding, kips						Limiting Unbraced Lengths, ft					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	L_p	L_r	L_p	L_r	L_p	L_r
1150	1720	1050	1580	931	1400	9.54	36.6	9.50	34.3	9.40	31.8
Available Strength in Tensile Rupture ($A_e = 0.75A_g$), kips						Area, in.^{2}					
P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	P_n/Ω_t	$\phi_t P_n$	38.3		35.1		31.1	
933	1400	855	1280	757	1140	Moment of Inertia, in.^{4}					
Available Strength in Shear, kips						I_x	I_y	I_x	I_y	I_x	I_y
V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$	V_n/Ω_v	$\phi_v V_n$	2460	278	2190	253	1910	220
259	388	249	373	221	331	r_y, in.					
Available Strength in Flexure about Y-Y Axis, kip-ft						2.70		2.69		2.66	
M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$	M_{ny}/Ω_b	$\phi_b M_{ny}$	r_x/r_y					
191	288	172	259	151	227	2.97		2.94		2.95	

Note: Heavy line indicates L_c/r equal to or greater than 200.

Figure 30: AISC 15th edition, Table 6-2 W18

Table 2: Beam and Girder Load Calculations

49									
50									
51			Beams						
52		Floor		Roof					
53	1	15.18	698.28	7.82	359.72	Floor Beams	Area(ft2)	load(lb)	kips
54	2	30.36	2793.12	15.64	1438.88	Bottom side	24	7920	7.92
55	3	37.62	4288.68	19.38	2209.32	Bottom 4' mid(12'	48	15840	15.84
56	4	11.583	406.5633	5.967	209.4417	3.5'&4' (12')	45	14850	14.85
57	5	30.228	2768.8848	15.572	1426.3952	Bottom 3.5'(12')	42	13860	13.86
58	6	15.84	728.64	8.16	391.68	Top 3.5'(16')	56	18480	18.48
59	7	14.85	668.25	7.65	344.25	Top side	114	37620	37.62
60	8	13.86	776.16	7.14	299.88	Wing side	46	15180	15.18
61	9	7.92	190.08	4.08	97.92	Wing middle	92	30360	30.36
62	15	18.48	1034.88	9.52	533.12	Triangle short	35.1	11583	11.583
63						Triangle long	91.6	30228	30.228
64									
65			Girders			Roof Beams	Area(ft2)	load(lb)	kips
66	10	60.72	11172.48	31.28	5755.52	Bottom side	24	4080	4.08
67	11	179.52	97658.88	92.48	50309.12	Bottom 4' mid(12'	48	8160	8.16
68	12	176.88	94807.68	91.12	48840.32	3.5'&4' (12')	45	7650	7.65
69	13	237.6	171072	122.4	88128	Bottom 3.5'(12')	42	7140	7.14
70	14	118.8	42768	61.2	22032	Top 3.5'(16')	56	9520	9.52
71	16	58.08	10222.08	29.92	5265.92	Top side	114	19380	19.38
72						Wing side	46	7820	7.82
73						Wing middle	92	15640	15.64
74						Triangle short	35.1	5967	5.967
75		Floor Girders	Area (ft2)	Load (lb)	kips	Triangle long	91.6	15572	15.572
76		Bottom	360	118800	118.8				
77		Middle	720	237600	237.6				
78		Top lower	536	176880	176.88				
79		Top	176	58080	58.08				
80		Wing lower	544	179520	179.52				
81		Wing two side	184	60720	60.72				
82									
83		Roof Girders	Area (ft2)	Load (lb)	kips				
84		Bottom	360	61200	61.2				
85		Middle	720	122400	122.4				
86		Top lower	536	91120	91.12				
87		Top	176	29920	29.92				
88		Wing lower	544	92480	92.48				
89		Wing two side	184	31280	31.28				

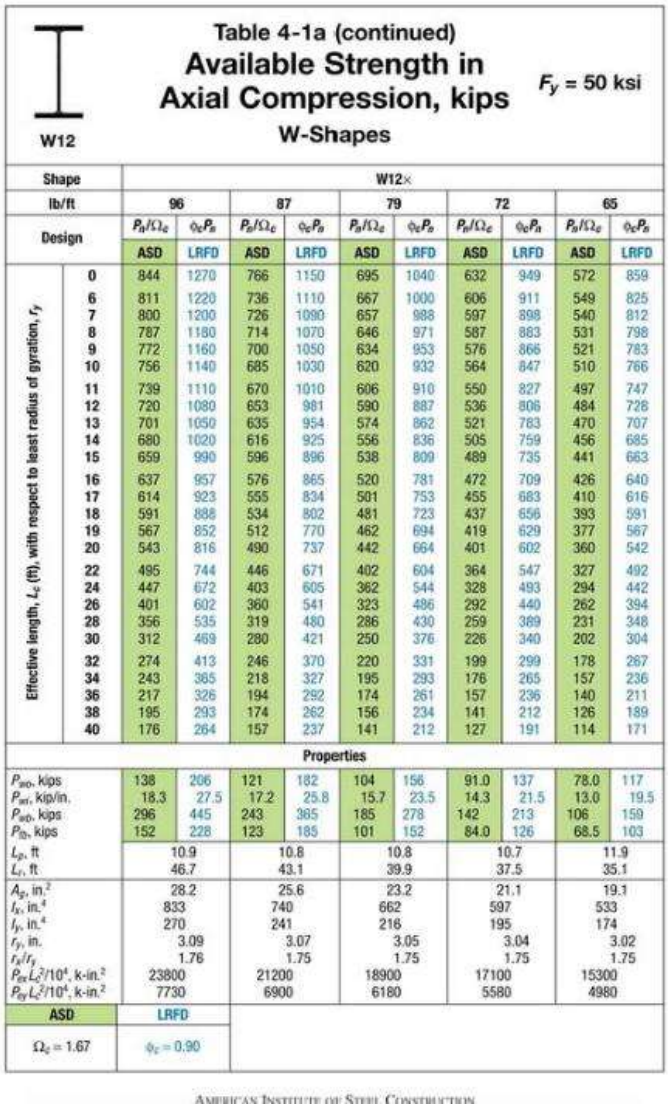


Table 4-1a (continued)

Available Strength in Axial Compression, kips

F_y = 50 ksi

W12

W-Shapes

Shape		W12×									
lb/ft		96		87		79		72		65	
Design		P_a/Ω_c	$\phi_c P_n$	P_a/Ω_c	$\phi_c P_n$	P_a/Ω_c	$\phi_c P_n$	P_a/Ω_c	$\phi_c P_n$	P_a/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length, L_c (ft), with respect to least radius of gyration, r_y	0	844	1270	766	1150	695	1040	632	949	572	859
	6	811	1220	736	1110	667	1000	606	911	549	825
	7	800	1200	726	1090	657	988	597	898	540	812
	8	787	1180	714	1070	646	971	587	883	531	798
	9	772	1160	700	1050	634	953	576	866	521	783
	10	756	1140	685	1030	620	932	564	847	510	766
	11	739	1110	670	1010	606	910	550	827	497	747
	12	720	1080	653	981	590	887	536	806	484	728
	13	701	1050	635	954	574	862	521	783	470	707
	14	680	1020	616	925	556	836	505	759	456	685
	15	659	990	596	896	538	809	489	735	441	663
	16	637	957	576	865	520	781	472	709	426	640
	17	614	923	555	834	501	753	455	683	410	616
	18	591	888	534	802	481	723	437	656	393	591
	19	567	852	512	770	462	694	419	629	377	567
	20	543	816	490	737	442	664	401	602	360	542
	22	495	744	446	671	402	604	364	547	327	492
	24	447	672	403	605	362	544	328	493	294	442
	26	401	602	360	541	323	486	292	440	262	394
	28	356	535	319	480	286	430	259	389	231	348
	30	312	469	280	421	250	376	226	340	202	304
	32	274	413	246	370	220	331	199	299	178	267
	34	243	365	218	327	195	293	176	265	157	236
	36	217	326	194	292	174	261	157	236	140	211
	38	195	293	174	262	156	234	141	212	126	189
	40	176	264	157	237	141	212	127	191	114	171
Properties											
P_{no}, kips		138	206	121	182	104	156	91.0	137	78.0	117
P_{wt}, kip/in.		18.3	27.5	17.2	25.8	15.7	23.5	14.3	21.5	13.0	19.5
P_{wb}, kips		296	445	243	365	185	278	142	213	106	159
P_{bb}, kips		152	228	123	185	101	152	84.0	126	68.5	103
L_p, ft		10.9		10.8		10.8		10.7		11.9	
L_r, ft		46.7		43.1		39.9		37.5		35.1	
A_g, in.^{2}		28.2		25.6		23.2		21.1		19.1	
I_x, in.^{4}		833		740		662		597		533	
I_y, in.^{4}		270		241		216		195		174	
r_y, in.		3.09		3.07		3.05		3.04		3.02	
r_x/r_y		1.76		1.75		1.75		1.75		1.75	
$P_{ex}L_c^2/10^4$, k-in.^{2}		23800		21200		18900		17100		15300	
$P_{ey}L_c^2/10^4$, k-in.^{2}		7730		6900		6180		5580		4980	
ASD	LRFD										
Ω_c = 1.67	ϕ_c = 0.90										

American Institute of Steel Construction

Figure 31: AISC 15th edition, Table 4-1a W12x87

Chapter 5: Citations

Ad classics: Geisel Library / William l. Pereira & Associates. (2014, November 11). ArchDaily. https://www.archdaily.com/566563/ad-classics-geisel-library-william-l-pereira-and-associates

Allen, E., & Iano, J. (2017). The architect's studio companion rules of thumb for preliminary design. https://nbn-resolving.org/urn:nbn:de:101:1-201705033786

American institute of steel construction. (2017). Steel construction manual. American institute of steel construction.

Building & zoning | city of worcester, ma. (n.d.). Retrieved March 22, 2022, from https://www.worcesterma.gov/building-zoning

Clifton park halfmoon public library. (2020). Quantum Engineering. https://quantumengineers.com/portfolio/clifton-park-halfmoon-public-library/

Deutscher, R. (2012). Stuttgart library interior [Photo]. https://www.flickr.com/photos/bobarc/7978201477/

Edwards, L, & Torcellini, P. Literature Review of the Effects of Natural Light on Building Occupants. United States. https://doi.org/10.2172/15000841

Floor plan. (n.d.). Retrieved March 24, 2022, from https://www.bpl.org/visit-central-library/maps/

Franta, G.; Anstead, K. (1994). "Daylighting Offers Great Opportunities." Window & Door Specifier-Design Lab, Spring; pp. 40-43.

Guignard, T. (2012). Cube [Photo]. https://www.flickr.com/photos/timtom/7198509756/

King, D. (2009). Clifton Park Halfmoon Public Library [Photo]. https://www.flickr.com/photos/davidking/3512796929/

Liberman, J. (1991). Light Medicine of the Future. New Mexico: Bear & Company Publishing

N., S. M. S. (2013, April 7). What is ATTENTIVENESS? Definition of ATTENTIVENESS (Psychology dictionary). https://psychologydictionary.org/attentiveness/

Palsson, O. (2014). Night view of the geisel library, University of California San Diego [Photo]. https://www.flickr.com/photos/opalsson/15163041049/

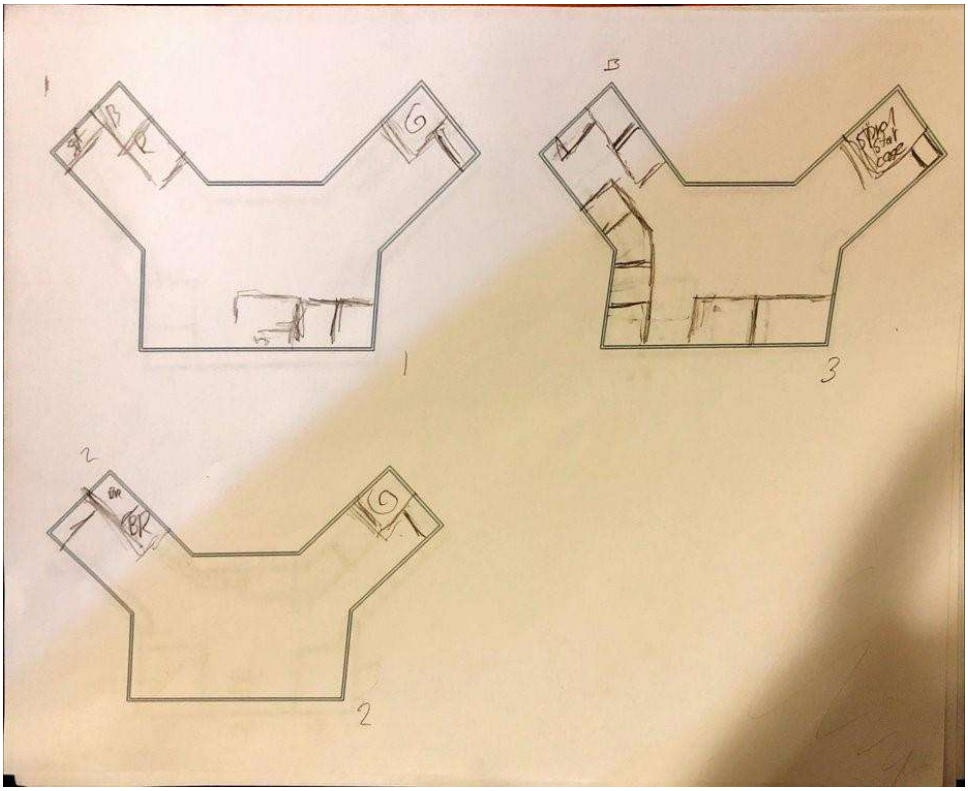
Robbins, Claude L. (1986). Daylighting Design and Analysis. New York: Van Nostrand Reinhold Company; pp. 4–13.

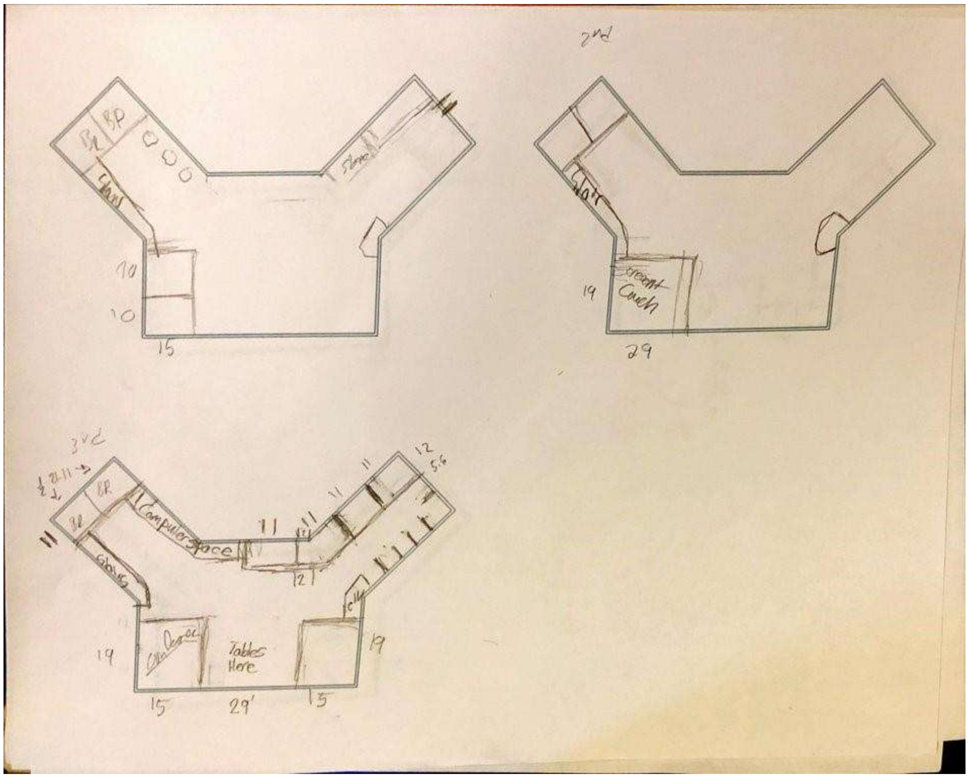
What is attention, types and disturbances. (2018, September 19). Bitbrain. https://www.bitbrain.com/blog/what-is-attention-types

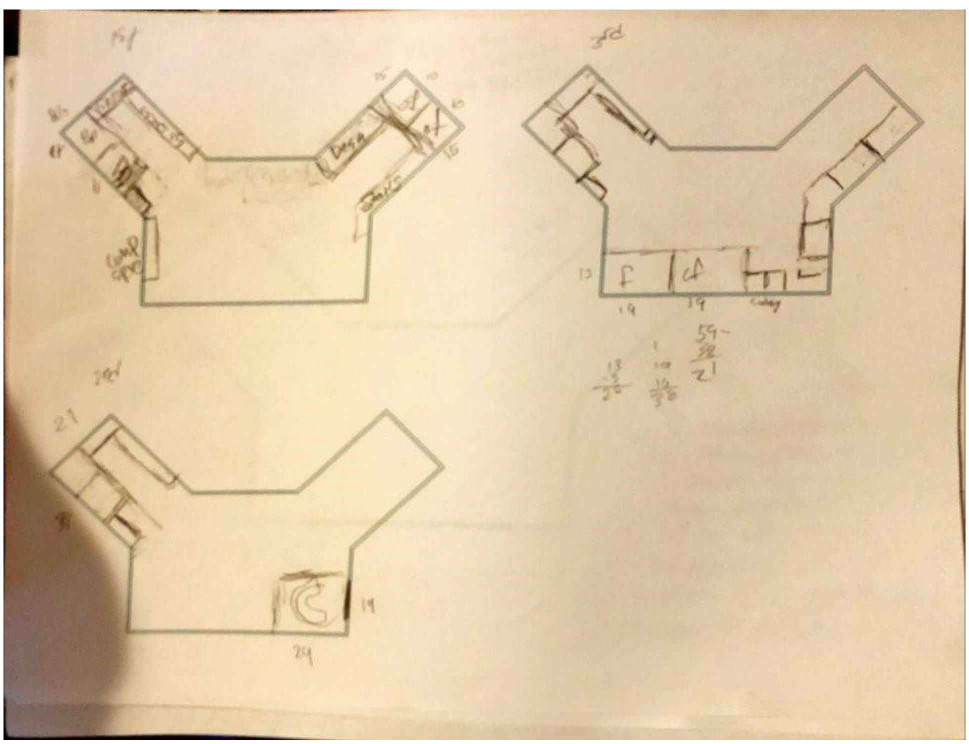
Zoning ordinance & map | city of worcester, ma. (n.d.). Retrieved March 22, 2022, from https://www.worcesterma.gov/planning-regulatory/zoning-ordinance-map

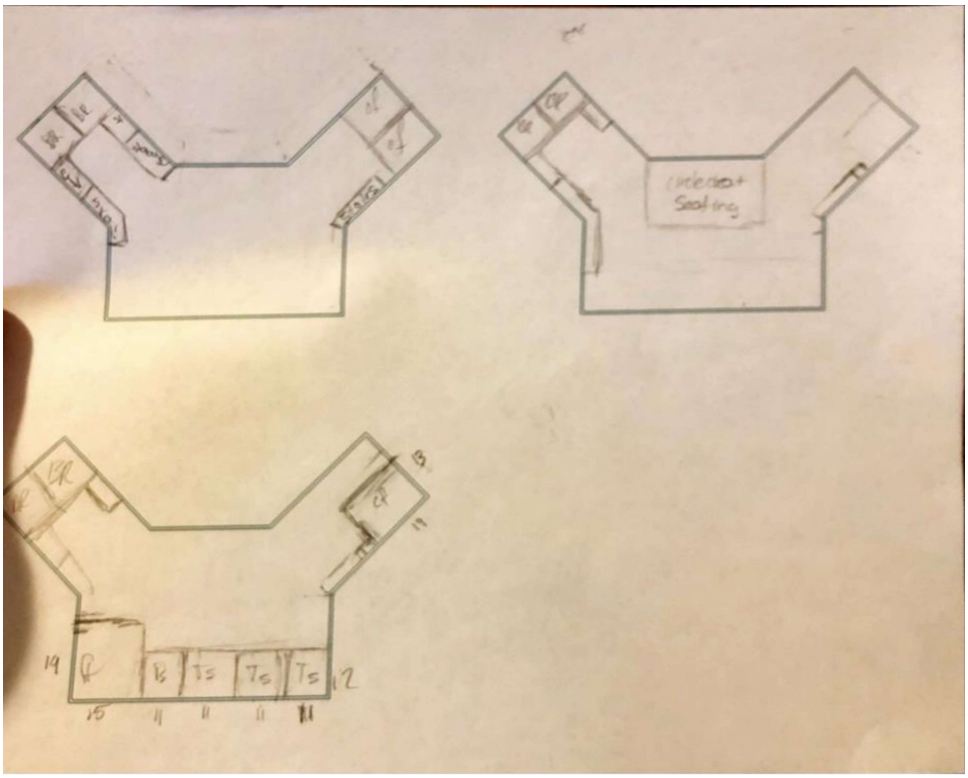
APPENDIX A:

Preliminary Floor-layout Sketches:



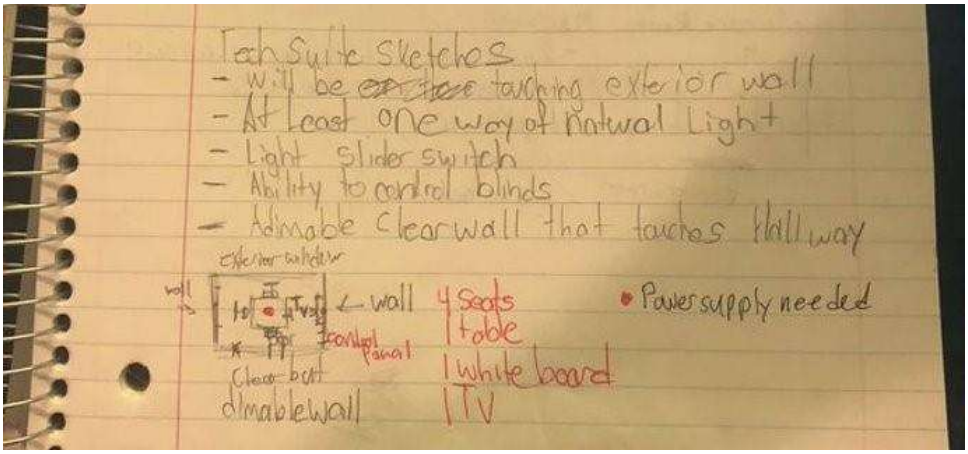

2nd
3rd
Computer space
Tables Here
15
29'
19

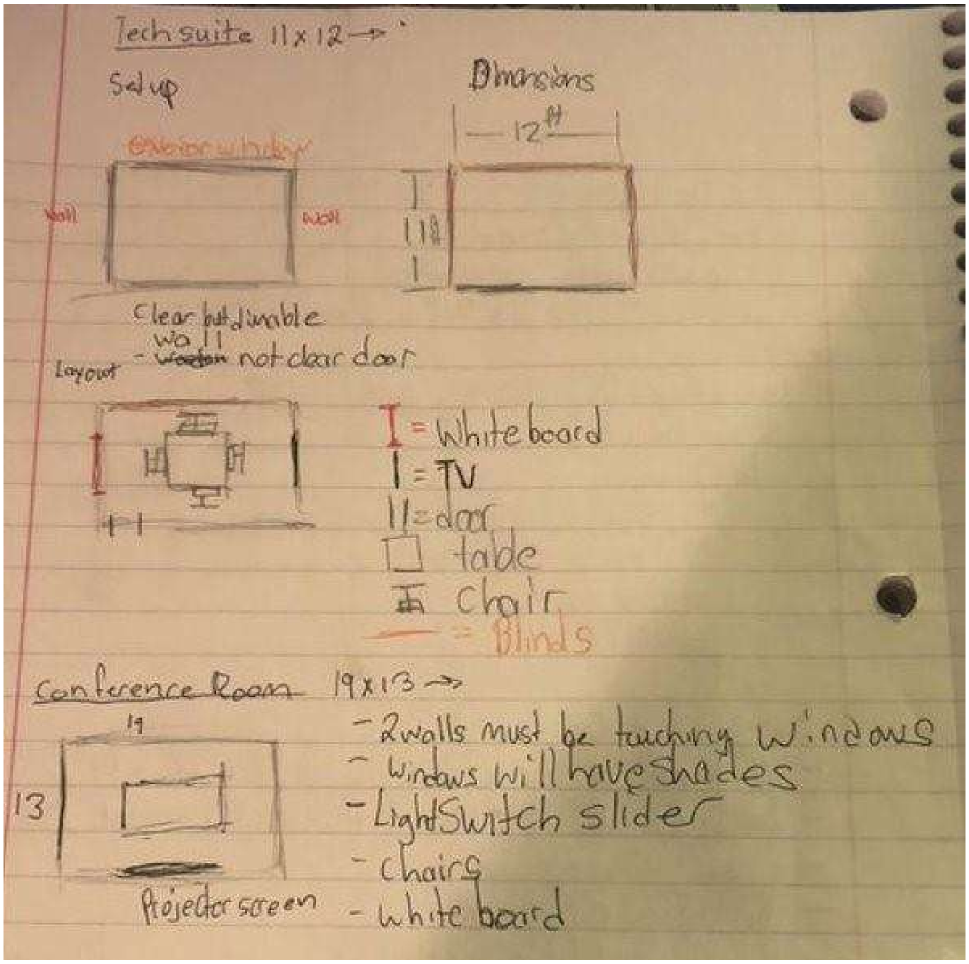

1st
3rd
2nd
29

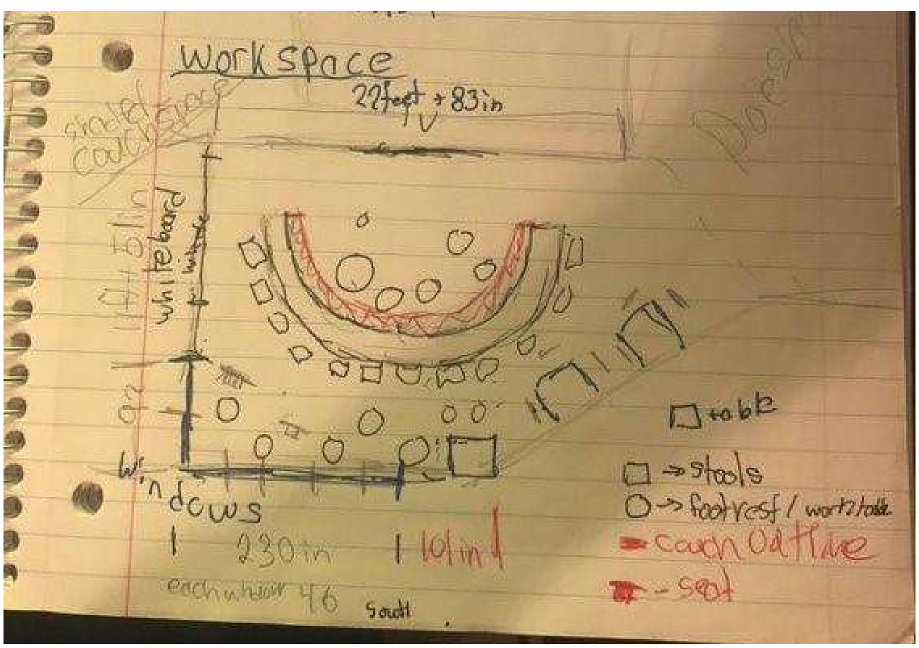


APPENDIX B:

Preliminary Sketches for rooms that were planned to be tested in (conference room and tech suite)




Tech suite 11x12
Set up
Dimensions
12 ft
11 ft
wall
wall
Clear but dimable
- wall not clear door
Layout
= Whiteboard
= TV
= door
table
Chair
= Blinds
Conference Room 19x13
19
13
- 2 walls must be touching windows
- windows will have shades
- LightSwitch slider
- chairs
- white board
Projector screen


Workspace
22feet + 83in
whiteboard
windows
230 in
101 in
each window 46
South
→ table
→ stools
→ footrest / work table
= couch outline
- seat