

I PRO 344 – Spring 2010

# Final Report

Cellular Towers in the Urban Environment



Team Leader: Timothy Lee  
Design Team Leader: Jacob Dohm  
Technical Team Leader: Amanda Chatman  
I PRO Lead Faculty: Jim Braband  
4/30/2010

TABLE OF CONTENTS

---

Executive Summary.....	3
Purpose and Objectives.....	3
Organization and Approach.....	5
Analysis and Findings .....	6
Conclusions and Recommendations.....	14
Appendices .....	15

## EXECUTIVE SUMMARY

---

The purpose of this project was to demonstrate the need of a cellular tower on the Illinois Institute of Technology (henceforth known as "IIT") main campus in Chicago and to express the desires of our sponsor, Charlie S Hayes, to construct a monopole structure in order to house each of the appropriate antennas. With his specialized understanding of building such a structure, we have had to perform a series of studies and surveys of the IIT community in addition to the neighborhoods surrounding the campus to identify all of the potential impacts that the tower would impose. The justification of such construction was to enhance wireless connectivity through phone services for all affected parties, especially during times of high traffic such as the White Sox games at the nearby U.S. Cellular Field.

Over the course of the semester, the team had researched and collected the relevant information in order to provide a rationalized solution that proposes a middle ground in which all identified sectors, hereby referred to as "stakeholders", would come to agree on in an appropriate and agreeable plan of action. The stakeholders have been condensed into four paramount groups: the school and conjoining IIT Facilities, the vision and specialization of Charlie Hayes, the student body and IIT's surrounding community, and the six primary carriers that service the general area. The proposition would be the result of a semester long consolidation of different components of such construction and the result of much consultation, especially within the parameters of the school's vision, the desires of the carriers to accept the lease offer, the impact of a structure on the IIT community, and the final approval for design execution by our sponsor before any formal submittal.

## PURPOSE AND OBJECTIVES

---

The primary purpose of the project had aligned with the ideas of our sponsor; his goal was to construct a cell phone tower on the IIT campus so that the carriers could lease different levels of the structure. A portion of the income would be devoted to the school, and the rest would be used to cover the cost of maintenance and operations of the equipment housed within the structure. Ultimately, this would allow Charlie Hayes to effectively step into the development of future towers in the Chicago urban area. To accomplish this, he had wished to introduce an infrastructure on IIT's campus, which he had assumed to possess a technological advantage compared to other possible sites. He hoped to collaborate with the architectural students of the team to overcome the aesthetic shortcomings of current towers.

There were several issues needing consideration for this project. One of the main concerns had regarded the aesthetics of current monopole designs. Monopoles are the only restriction set by Chicago zoning regulations for a freestanding communications tower. However, we also needed to keep the overall cost of the project to a minimum while allowing a degree of creativity. The design process put forth a strong emphasis on retaining the interests of the four stakeholders.

**Comment [MSOffice1]:** The wording of this sentence is confusing.



First, we had considered the effect that the design would have on the IIT community. To quantify the opinions of the community, we had distributed and collected data using two surveys--one that was specific to IIT students and the other that regarded the interests of the surrounding community. Additional information and explanation are enclosed later in this report. With this information and the subsequent analyses, the group had ventured into a series of concurrent site interpretations to give a thorough presentation of the conditions of IIT as a potential starting point.

In terms of the interests of Charlie Hayes, he has administered the construction of several different types of towers, including monopole, guyed, lattice, and stealth, all within the context of a rural environment. He had observed that the cell tower industry is in constant flux and realized that there will be a compounding demand of towers within urban settings. The Chicago area has a significant number of building- and roof-mounted antennas with minute open space for expansion and constant equipment management. Charlie Hayes has experience with towers that are acceptable under zoning regulations of a rural setting, and wishes to make the necessary changes in design to retrofit the existing tower designs into an urban area. By combining these two factors, there is an increasing possibility to construct a cell tower on IIT's main campus.



## ORGANIZATION AND APPROACH

---

As a group, we had concluded that dividing into two sub-teams was most efficient in distributing the workload into different specialized groups. The design team, comprised of all architecture majors, focused on the structure and aesthetics of the tower. Their main concern was to address the entirety of the tower and to create something that would capture the essence of the school's architecture and design concerns while integrating their individual creativity. With their collaborative efforts, they were able to conceptualize the paramount issues with a typical tower and revitalize a sense of school spirit and an edge of modernism, finalized into three distinct designs.

The technical team, made up of two architecture majors and three engineers, were responsible for collecting the fundamentals of tower construction. The highlight of their research was to capture the impact of a tower onto the communities of IIT students and the surrounding neighbors. Utilizing several surveys and questionnaires, which were distributed through Facebook to IIT students and through SurveyMonkey to IIT community leaders, they were able to collect and analyze the disparity in erecting a 150-foot tall structure between differences in views. Details of the survey can be found in the appendix.

The purpose of creating such surveys was to epitomize the consensus of students. In the process of brainstorming the potential questions, we had to weigh the advantages and consequences of asking an open-ended question rather than one with pre-selected answers. We wanted the questionnaire to be answered quickly, but also to provide enough information so that the design team could keep the considerations as guidelines for the aesthetics of the tower. In the student questionnaire in particular, it was common to see several impulsive answers, but we were fortunate to receive some responses that provided the brevity yet thoroughness that were beneficial to the design team's imminent tasks.

We also discovered the necessity to pose similar questions to the IIT community leaders, particularly those with strong opposition to the tower itself. It was difficult to collect this information due to the absence of a considerable response size, but we managed to use one in particular that assisted in their gathered opinions. The height of the tower was duly mentioned in their description of the suggestion, but they saw that the convenience of improved reception in the neighborhood easily outweighed the unappealing of the structure itself. There were no further comments that could have been of much help, so we agreed that the survey would be redistributed once a formidable design had surfaced. We also considered the needs of nearby police and fire stations, even those of the school's Public Service, though these would be referenced again upon design completion.

An obstacle in collecting the information was to sift through the opinions so that the tower compensates as an effort to effectively convey the IIT branding while retaining an appeal to visitors and residents alike. The technical team had acted as consultants for the architects in the design team, refining their understanding of the zoning codes and design constraints that would have otherwise hindered the progress of the project. With the collective knowledge of all team members, the process of design and technicalities were pooled to illustrate an all-inclusive concept with all the other necessities of project success considered.

**Comment [MSOffice2]:** This section should cover how you conducted your research, i.e. how you chose to approach the problem and which research methods you used. Your team structure, work breakdown and schedule are irrelevant for the purposes of this report.



With the help of our sponsor, whose understanding of monopole construction surpasses all of ours, we were able to move efficiently from task to task in order to meet deadlines and essentially move forward with the design. Towards the last few weeks of the project, we were entitled to building a series of physical and illustrative models to illustrate the effects of the tower's presence on IIT's campus, and to provide an appropriate level of justification for each individual consideration. The amount of cohesion between the group members and their dedication to project success pushed us towards achieving our end goal—improving the existing conditions of cell phone reception to the IIT and neighboring areas while encapsulating the aesthetic demands of Chicago architecture.

### ANALYSIS AND FINDINGS

---

One of the major stakeholders in placing a cell tower on IIT's campus is the surrounding community. Residents of the Bronzeville area would be passing this cell tower regularly. Therefore, our group attempted to reach out to the community to get their input on cell towers. LeRoy Kennedy, Vice President of External Affairs at IIT, was consulted to help the group reach the community surrounding IIT. Leroy supplied us with the contacts that are mentioned in Appendix C. Our attempts of getting responses from these contacts were unsuccessful; however, a survey was created and important community contacts were compiled for future implementation. Other supplemental information relevant to the students' opinions is also in the appendices, providing insight to the conflict of interests pertinent to the construction.

Another part of our research was to collect information from various members of the IIT Administration. One of the first members of this group we had talked to was Terry Frigo, the Vice-President of Facilities. We had discovered several things from the visit, and the biggest piece of information had drastically changed our design criteria. We were initially inclined to rid our tower of the ugly building at the base by placing it underground. After our interview with Terry, we had realized that the water table was too high which had made underground construction difficult due to the financial constraints of the project. We had learned that there were two antenna arrays on the IIT campus already. One is located at the top of IIT Tower, which is owned by AT&T who pays IIT \$40,000 a year. The other is owned by Verizon Wireless, which located on Machinery Hall. The value of the lease could not be disclosed due to privacy reasons. The interview discovered that the site South of Galvin Library should also be removed from our potential site list due to existing underground piping and that IIT has no current objections to a cell tower being built on campus. We were directed to Donna Robertson and Ophir Trigalo to gain additional insight from the school's primary administration members.

Ophir Trigalo is the Chief Information Officer at IIT and is currently working on contract negotiations for the Rice Lake Campus and potentially Moffett Campus for implementing cell towers. His main goal is to wirelessly integrate all of the IIT campuses through relays located in Willis Tower. The best way to make this connection is for antenna arrays to be mounted on a cell tower. The company he is currently working with is SBA Communications, who is a major provider of towers and a competitor to our sponsor. Ophir will turn his attention towards Moffett Campus once the Rice Lake negotiations are final,



and that is where our IPRO would step in. He is willing to possibly implement our selected design for the Moffett Campus tower. The Moffett campus is located on 6502 South Archer Road, in Summit Argo, Illinois. Being three miles west of Midway Airport, the site offers a prime location for our sponsor's goal of building towers in Chicago.



**\*\*MOFFETT INFORMATION HERE\*\***

In addition to serving as the Dean of the College of Architecture, Donna Robertson is also the co-chair of campus planning with John Collins, who is also the Vice President of Capital Projects. The interview with Donna had surfaced some of her insights on the project proposal, focusing mainly on the location of the site. Her preference had indicated that the soccer field was the best option for the group. She was intrigued with the idea of placing a structure that functions as a centralized social area on Farr Field next to the band shell, perhaps also serving an additional purpose of storing sports equipment or even a locker room. It was hard to differentiate whether it was a good or bad decision based on her statements. At the end of the discussion, she had indicated that the planning group meets on a need basis, citing that when there are finalized plans for the structure, a hearing can be arranged for our proposition.

An additional interview was held with two tower maintenance workers as an effort to gain information on the process of repairing and keeping the equipment in good condition. Although a lot of technical jargon was introduced, the interview had provided valuable information that should be considered in placing the equipment in the structure. One of the more interesting things we had learned while conducting the interview was the amount of coordination necessary between these workers and the individual cell phone carriers. It was evident that in order to convince the carriers initially that we would require sufficient information about the site and the justification that reception would improve with the placement of antennas. As a final note, the men had indicated some of the typical construction methods and specifications in the sizing of equipment, which had reduced a lot of guesswork in the drawings.

It is a high priority for this tower to match the look and feel of the IIT campus. In the past few years, IIT has strived to be a sustainable and green campus. In designing this tower, we had focused a lot on the "SustainabilITy" theme. Using alternative energy to

account for a portion of the tower's power requirements, in addition to branding the tower with a sense of sustainable efforts, we had started to investigate different wind turbine configurations. The conventional windmill design proved to be infeasible due to excess costs required for installation and maintenance. The windmill also required too much space at the top of the tower, which is where the antennas needed to be fixed in their positions. It also posed several issues in the load distribution, whether the tower could still function with additional weight on the top. However, there are currently smaller and more compact helical wind turbines that are on the market. The design of these wind turbines are lightweight and have cut-in wind speed requirements when compared to the conventional windmill.

From researching all of the available wind turbines, two companies appealed to potential integration to our cell tower design. Helix Wind Turbines, one of our options in a wind turbine system, offers several different wind turbine designs with the capacity to be attached to a monopole. See the appendices for additional information on the cost, appearance, specifications, and estimated energy outputs. The other company, Aerotecture, was based in Chicago. Their wind turbines are not as small as the Helix Wind turbines, but they have implemented their turbines onto the rooftops of buildings in Chicago. If we were to go with Aerotecture turbines, which are typically roof-mounted, they would be placed on the roof with the building's mechanical equipment. The specifications and cost estimations are included in Appendix G.

In searching the campus for a proper site for the cell tower, we had found two appropriate sites. One site was in a secluded area, and the other in a more public and high access area. The first is located by the soccer fields next to the train tracks on the Northwest corner of campus. We had chosen this site for its semi-public and open area. It has great visibility from the highway and passing trains. This site is optimal because it is on the edge of campus where few people visit so it could draw more people. The second site is located south of the Galvin Library. We had chosen this site because its visibility and the heavy amount of pedestrian traffic. We had wanted to use this site to bring more attention to the cell tower structure and to get people to interact with it, almost as a monument. After the interview with Donna Robertson, we had discovered that building on the field would be near impossible due to the existing cooling tower and system of pipes underground.

**Comment [MSOffice3]:** The wording of this sentence is a bit clunky.

The site decision was based on areas of the campus that were open with minimized pedestrian and vehicular traffic as well as being distant from any building. It was a response to the majority of the opinions based on the number of student surveys we received. Most had suggested an area on the edge of campus. The soccer field was the best option based on these criterions. With the tower located on this site, it will get some visibility from the highway while retaining maximum sun and wind for the sustainability portions of its design. Overall, of the potential proposed sites on IIT's campus, this one seemed far superior to the others.

In the design process of the "Circle Building", we had stated a few objectives that the design would meet. The first was a simple building - something conventional within the familiarity of Charlie Hayes. Second, we had wanted to eliminate what we had viewed as ugly fences. It was agreed that containing a building on the campus with a fence would not match the surroundings. Third, we had eliminated the need for excessive maintenance.





This had proved to be inaccurate, as Charlie had mentioned after the presentation that the ease of maintenance on the antennas were pivotal to the functions of a cell tower. We needed to provide ample leeway so that the maintenance crew could make adjustments and repairs as necessary without having the hassles of avoiding existing members of the structure. Fourth, we had desired a smooth and elegant building.

We took these elements and put together a project that had answered all of our challenges. Our design had used the building to wrap around the simple monopole in order to protect the monopole and to eliminate the need for a fence while protecting the equipment inside. We had planned to use poured-on-site concrete with an aesthetic finish to give the building a smooth finish while keep excessive costs minimal. The building was two stories tall to support up to six carriers and to reduce the footprint on the site. Overall, this design is the simplest, cheapest, and attempts to align with the recommendations of Charlie Hayes, while retaining the feeling of newness and innovation.

The design of the second tower proposal was an attempt to change the aesthetic appeal of the traditional monopole tower while integrating methods of sustainability, namely solar energy. The tower was placed in the space between the L-shaped building and the train tracks wall to create an isolated work area for maintenance and to eliminate the undesired fencing. The tower and the carrier antennas were within the traditional framework of current tower design. However, this design would also include a secondary skin or screen. This skin would be used to hide the antennas and integrate photovoltaic cells that would capture the sun's energy. The energy captured will be used provide some energy to air condition the building in the summer and potentially light the soccer field during certain events. This design was a step away from the conventional, but it had introduced new ideas of innovation that would benefit our sponsor in name recognition as well as incorporating the IIT name into the external skin.

After Charlie Hayes' visit, it was apparent that he had liked the building layout and its orientation in comparison to the tower, but he was not enthralled by the skin. He had suggested an interest in retaining the existing layout while introducing the wind turbines back into the tower structure. He had mentioned the ease in incorporating this into the design especially because the tower members were not prefabricated; instead, the drawings would note that mounting brackets would be installed below the lowest antenna branch so that two turbines could be attached thereafter. With these considerations, the possibility of construction had become clear.

As a group, we had researched the idea of a cell tower. We thought that it might be possible to look in another direction for our IPRO for a third alternative, completely different in function from the others. With further research, we had decided to create a structure that would become a symbol for the campus of IIT, similar to Crown Hall for the School of Architecture. As we ventured further into this concept, we had decided to construct a bell tower for the campus. The bell tower would consist of four large pillars as support. The bottom level would have become an open plaza much like a band shell that currently exists on Farr Field next to the Quad. The next level would be the mechanical room for the cell tower equipment, followed by the bell equipment, and a cell tower antenna would be hidden between the tower's pillars at the top.



By placing the mechanical building above the ground plan, it would create the possibility of an outdoor multipurpose space. The tower would be placed on Farr Field, lined accordingly with the Greek houses, and replacing the existing band shell altogether. The tower could have served as symbol for the IIT campus and an outdoor plaza space, double functioning as a cell tower. With further research, we had decided that the idea would be very impractical and extremely costly. The tower design was not in the direction that our sponsor wanted our IPRO to pursue. We had continued with our other designs to satisfy our IPRO's objective.

As we reviewed the zoning codes to build a tower in Chicago, we had found these as the most relevant to our project:

**General Standards:** These are the basic standards for all wireless communications that include FCC and FAA standards. All of the regulations our sponsor already knows.

- No artificial lighting on towers or antennas unless required by the FAA.
- Towers must have a galvanized steel finish or be painted neutral colors.

**Freestanding Structures:**

- Tower cannot rise more than 150 ft from the curb (M, PMD, T)
- Tower must be of a monopole construction (cylindrical, tapering steel tubes without guy wires).
- Tower must be constructed so that if failure does occur, it collapses on itself and not on surrounding structures.
- Freestanding facilities must be enclosed by a six-foot fence with an anti climbing device that is not barbed or razor wire.
- Wireless communication facilities must be landscaped with plants to screen the view of the tower and equipment from adjacent residential properties

**Co-Location by attachment to existing structure:** This subsection addresses the installation of a tower or antenna on an existing structure, other than a wireless communication facility tower, including but not limited to buildings, light poles, water towers, commercial *signs*, church steeples, and any other freestanding structures.

- Antenna dimensions: 6 feet high or wide, if the structure is more than 40 feet high.
- Antenna Projection: The antenna of such a *co-located facility* may not project more than 3 feet from the side of the structure, nor may any equipment shelter or platform or other supporting electrical or mechanical equipment that is mounted on the structure be located within 5 feet of the outer edge of the structure.

- **Antenna Design:** The antenna and associated equipment of such a *co-located facility* must be of a neutral color that is identical to, or closely compatible with, the color of the supporting structure or building so as to make the antenna and associated equipment as visually unobtrusive as possible.

**Key Points**

The IIT campus is considered a planned development. Most of these regulations apply to all zoning districts, however the height requirement above is for manufacturing, planned manufacturing, and transportation districts. There are no height requirements shown for planned developments. There are no fence requirements of co-location facilities, such as our tower. In addition, non-federally mandated requirements can be waived by the Zoning Board of Appeals. A copy of the aforementioned building restrictions can be found in the "Municipal Code of Chicago", last updated on December 16, 2009, in Title 17, Chapter 17-9, Section 0118 entitled "Wireless Communication Facilities".

**Initial Cost:** The initial cost estimates were made by using some of our sponsor's previous projects as guidelines.

Task	Cost (\$)
Permits, Engineering	20,000
Foundation	50,000
Site Work	25,000
Tower	90,000
Tower Erection	20,000
Grounding	10,000
Fence	10,000
Generator	25,000
Landscaping	10,000
<b>Total</b>	<b>\$260,000</b>

## Option#1 Circle Tower Design

**Initial Cost=** \$260,000

**Base Building Cost=**  $\$3.70/\text{ft}^2 (\text{materials}) * 2,350 \text{ ft}^2 + \$25/\text{hr} * .75\text{hrs}/\text{ft}^2 (\text{labor}) * 2,350 \text{ ft}^2 =$  \$52,755

**Materials:** Concrete

**Square Footage:** Two story with 1,175 ft<sup>2</sup>/per floor, Six 140 ft<sup>2</sup> bays for carriers

**Reoccurring Costs** (electric) = 32,400 KWH/carrier/year \* \$0.15/KWH = \$4,860/carrier/year

**Income**  $\approx$  \$2,000/month/carrier

## Option#2 Sustainable Design

**Initial Cost =** \$260,000

**Base Building Cost=**  $\$3.70/\text{ft}^2 (\text{materials}) * 600 \text{ ft}^2 + \$25/\text{hr} * .75\text{hrs}/\text{ft}^2 (\text{labor}) * 600 \text{ ft}^2 =$  \$13,470

**Materials:** Stone like on the train tracks over concrete

**Square Footage:** Two 10ft x 30ft buildings

**Aesthetic Improvements:** Cost for Helix Wind Turbine S594 = \$16,000/turbine\*2 Turbines = \$32,000

**Reoccurring Costs** (electric) = 32,400 KWH/carrier/year

\* \$0.15/KWH = \$4,860/carrier/year

**Income from carriers**  $\approx$  \$2,000/month/carrier

**Income from turbines**  $\approx$  1300 KWH/year/turbine\*\$0.15/KWH = \$195/turbine

## Option#3 Bell Tower Design

**Initial Cost =** \$260,000

**Base Building Cost Factors:** Would need a sponsor for initial cost

**Materials:**

**Square Footage:**

**Reoccurring Costs** (electric) = 32,400 KWH/carrier/year \* \$0.15/KWH = \$4,860/carrier/year

**Income**  $\approx$  \$2,000/month/carrier

## CONCLUSIONS AND RECOMMENDATIONS

---

The main objective of this IPRO was to design a cell tower that fit into the urban setting as well as IIT's campus. The technical sub team had worked on creating and analyzing surveys, and has researched present cellular tower configurations and new ways to harness renewable energy. The design team has put their efforts into finding a tower site on IIT's campus and creating three innovative cellular tower designs. Our group has been successful in finding the zoning codes of cell tower construction, contacting and interviewing IIT administration, researching wind turbines that can possibly be incorporated into a design, creating models and sketches of three tower designs, and getting input from IIT students.

Our group has concluded that the capacity requirement of cellular service for the IIT community will only go up in the future. Therefore, IIT would benefit greatly from the construction of a tower on campus. For the future of this project, many steps need to be taken for construction to be approved. This project needs more feedback from the surrounding community of IIT and the IIT administration. With three designs on the table, input from the community will help guide this project in the right direction. In addition, more technical data must be gathered so that the need of a cellular tower can be supported with quantifiable data. The progress made this semester is a great start to this project. With hard work and strategic task planning, the ultimate goal of creating the urban cellular tower can be obtained in the near future.

---

APPENDICES

---

**Appendices Index**

- Appendix A: Budget
- Appendix B: Team Information
- Appendix C: Contact List
- Appendix D: Background Information
- Appendix E: Student Survey and Analysis
- Appendix F: Community Survey
- Appendix G: Turbine Summary
- Appendix H: Site Analyses
- Appendix I: Circle Building
- Appendix J: Bell Tower Building
- Appendix K: Sustainable Building
- Appendix L: Building Plans, Sections, and Elevations



**Appendix A: Budget**

*Proposed Budget*

\$200 - Models

(Two Small-scale models)

Materials – MDF, Bass Wood, Acrylic

\$20 - printing Material

\$250 - site visits & interviews

\$100 - Survey Incentive

Total = \$570

*Actual Budget*

\$30 – Models

MDF - \$20

Basswood - \$10

\$170 – Site Visits and Interviews

Gas - \$50

Lunch - \$60

Sponsor Visit - \$30

Presentation Critique - \$30

Total = \$200



**Appendix B: Team Information**

<b>Name</b>	<b>Major</b>	<b>Role</b>
Chan, Ronald	ARCH	Design Team Member
Chatman, Amanda	MMAE & MATH	Tech Team Leader
Divito, Michael	MMAE	Tech Team Member
Dohm, Jacob	ARCH	Design Team Leader
Ghafoori, Marc	ARCH	Design Team Member
Lee, Timothy	ARCH	Team Leader
Perizes, Fotis	ARCH	Tech/Design Team Member
Reznicek, Dustin	ARCH	Design Team Member
Roberson, Jon	CAEE	Tech Team Member

**Appendix C: Contact List**

Name	Position	Phone Number	Email
Prishant Patel	Sales Manager, Clear/Sprint	██████████	motobapu@yahoo.com
Agustin Gonzalez	Recruiter, T-Mobile	██████████	agonzalez@mymobile1.com
Rich Sweis	Dealer, Cricket/Clear		
Gabbie Sarsok	Sales Rep, AT&T	██████████	gs880@att.com
LeRoy Kennedy	Vice President, Community Affairs and Outreach Programs	██████████	kennedy@iit.edu
Terry Frigo	Vice President, Facilities	██████████	<a href="mailto:frigo@iit.edu">frigo@iit.edu</a>
Ophir Trigalo	Chief Information Officer, IIT		<a href="mailto:trigalo@iit.edu">trigalo@iit.edu</a>
Ramos Tolbert	Assistant Director of Operations, Public Safety	██████████	<a href="mailto:tolbertr@iit.edu">tolbertr@iit.edu</a>

### **Appendix D: Background Information**

Charles Hayes has provided customer-specific services and facilities to the telecommunications industry for over 20 years. He currently owns the land and towers of more than 40 telecommunications sites located in Indiana, Michigan, Ohio and Texas. Tower sites are located in city centers, neighborhoods and rural communities. Charles has used a variety of tower designs including monopole, lattice, guyed-tower and stealth.

As the number of cell phone users continues to increase, capacity is becoming an issue, especially in highly populated urban areas such as Chicago. The urban setting poses unique design considerations for cellular towers. One of the largest constraints when designing a cellular tower in an urban setting is space. Ground space is limited, which eliminates traditional tower designs such as guyed towers or any truss designs that requires a large base. Additionally, large building density poses a threat to signal transmissions.

There are over 100,000 cellular towers in the United States. There have been many attempts at creating a cellular tower site that is more aesthetically pleasing. Stealth towers have been constructed to hide the appearance of the tower. For example, towers have been designed to look like palm trees as well as a cross in front of a church. Although these designs hide most of the tower, they often are more expensive and have a lower capacity than a normal tower. Another common problem in cell tower sites is the up keeping of the shelters and equipment at the ground level of the tower. It is typical of some sights to be completely stranded after the initial construction of the tower that yields an unattractive site.

Considering all of these constraints, the city setting requires a high concentration of cellular towers. The IIT campus will serve as a "representative" location on Chicago's south side for purposes of this project, but the overall objective is to develop a concept and design for a self-contained, secure and environmentally friendly facility that can adapted to almost any other urban location. Charles is interested in building a number of sites within the Chicago city limits that would be more secure and aesthetically pleasing than those you will notice as you tour the local community. His goal is to create a concept that represents a radical departure from conventional cell tower sites and quickly build a prototype site that could be shown to the wireless industry. In this regard, Charles has some preliminary ideas that would use a monopole design, but acknowledges that this is only a starting point for the project.

One of our goals is to create a cellular site that can be seen as a model example of a tower for the urban setting. In order to reach this goal, we must approach all aspects of this project in an ethical matter. The main ethical situation that the group needs to address is the consent and approval of the IIT and south Chicago community. It is very important that the surrounding community is aware of the building of this cellular tower and approves of the additions to our environment.

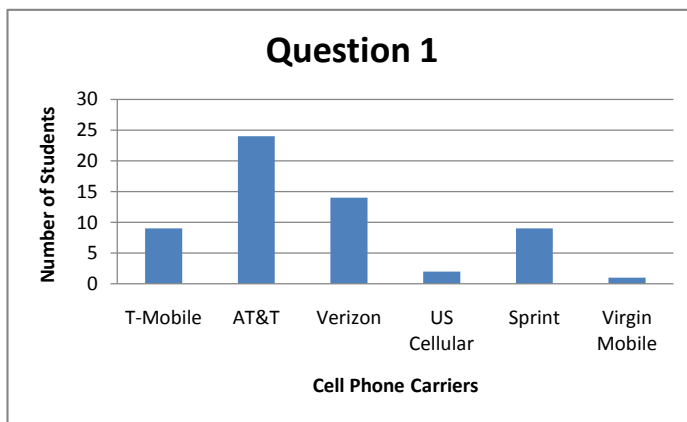
**Appendix E: Student Survey and Analysis**

**Student Survey Summary**

The survey link to Survey Monkey was given out on Facebook and spread by word of mouth. There were a total of 60 surveys started and 54 surveys completed. Additionally, there were five paper questionnaires submitted.

- **Question 1: What provider do you use?**

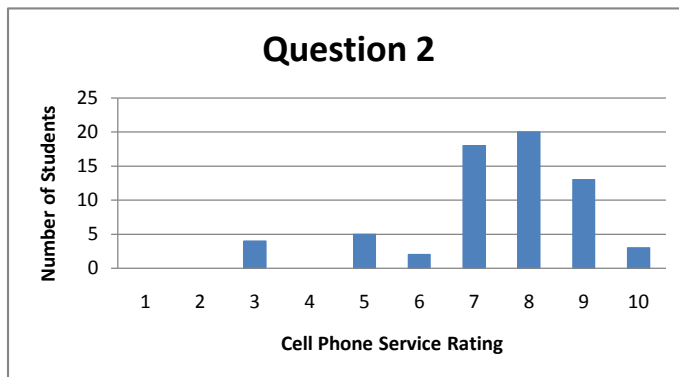
As you can see from the figure below, almost half of the students who completed this survey are on the AT&T network. Verizon, T-mobile, and Sprint make up the vast majority of the other half of students.



**Figure 1:** Different cell phone carrier used by the IIT students

- **Question 2: How would you rate your service on a scale from 1 to 10 with 10 excellent?**

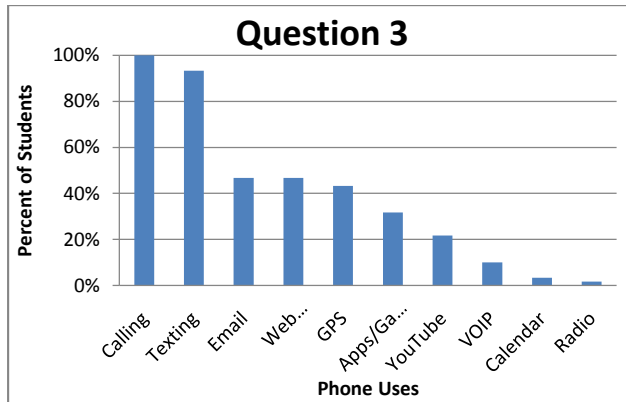
The mode of this question is 8, and the mean is 7.42. From looking at the figure below, it seems that the majority of students are content with their current service.



**Figure 2:** Student cell phone service ratings

- **Question 3: What do you use your phone for?**

For this question, the students were given multiple choices, which included calling, email, texting, and more. Every student says that they use their phones for calling. Over 90% of the students say they use their phones for texting as well. Figure 3 shows the percentage of students who circled each phone usage.



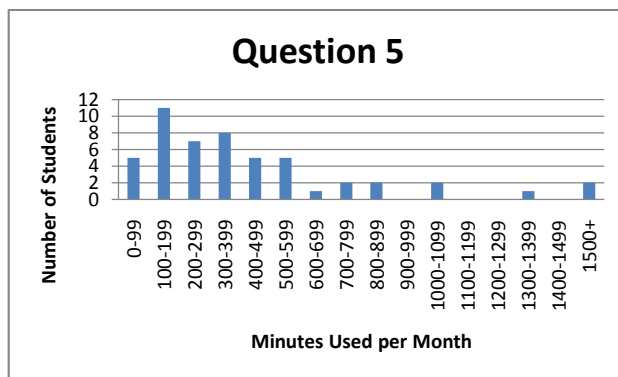
**Figure 3:** Percent of student who use each capability on their phone

- **Question 4: Is there an area on campus/local area that you don't receive coverage?**

This is an open-ended question. Thirty students simply answered no. Six people say they do not receive coverage in buildings. Eleven students say they do not receive coverage in basements. However, there are no specific locations on campus mentioned.

- **Question 5: On average, how many minutes do you use per month?**

The mode for this question is 100-199 minutes per month. The approximate average for this question is about 330-430 minutes per month. The figure on below shows the number of student responses for each minute range.



**Figure 4:** The amount of student responses for each minute range

**Aesthetics Questions:**

- **Question 1: What are your first impressions of a cell tower such as the one pictured above?**

**Question 2: What are some of your likes and dislikes about the design?**

The picture these two questions are referring is of a monopole tower design. Because these are open-ended questions, it is more difficult to quantify results than the previous questions. However, there are repeating responses for both questions. For question one, most of the responses are neutral and observant. The bulk of the students simply say that the monopole is large. A few students say the tower is ugly.

For the second question, there are approximately 20 “like” comments of the tower. The main aspects of the tower that the students like are the simplicity, functionality, and minimalistic look. There are 38 “dislike” comments of the tower. The majority of these comments consist of calling the tower ugly, intrusive, too tall, and out of place.

- **Question 3: How/what would you do to make it better?**

Just like the first two questions, there are a few common responses for question 3. About seven responses suggest that the tower should blend and fit in more with the environment surrounding it. Some students simply say make the tower match its surroundings, and others specifically suggest painting the pole a more neutral color. Six responses are related to the general idea of using alternative methods besides hanging antennas on a freestanding tower. The main suggestion is to put antennas on a pre-existing building instead of building a new tower.

Four students say that the monopole is fine the way it is and should not be changed. Others also say to make the tower multi-functional, such as put a windmill at the top to collect wind energy. There are a few other random responses, but most of them relate to these general topics.

- **Question 4: If you had the option, where would you place a cell tower on the IIT campus?**

Out of the 46 responses to this question, 9 students recommend putting the cellular antennas on top of the IITRI building. Most of the suggested locations on campus are on the edge of the campus. Some suggested sites are by the train tracks near Main building, Stuart building near the projects, VanderCook, and near Keating. Six students specifically suggest the location to be somewhere on the edge of campus or somewhere where the tower will not stand out. Five student suggest either an off campus location or no location at all.

From the results, we can see that AT&T is the most used service on IIT campus, and on average, the students are satisfied with their current service. In addition, besides the common problem of not having good cell coverage in basements, there were no specific areas mentioned with bad coverage. However, question 3 shows that currently only about 45% of the students use web browsing, GPS, and email on their phones. The amount of data usage on cell phones is currently increasing. As the average data usage increases, so does the required cellular capacity of that given area.

**Appendix F: Community Survey**

Note: Despite our efforts to gather sufficient information about the community, there was only one response. It is our intent to collect subsequent information once the design goes through future iterations.

**1. What is your role in the Bronzeville community?**

President and Founder of Bronzeville Area Residents and Commerce Council

**2. Do you work or live near the IIT campus?**

Yes.

**3. Are you familiar with the IIT campus?**

Yes.

**4. Who is your cell phone carrier? Are you satisfied with their service?**

T-Mobile. Yes.

**5. Would you support the idea of constructing a new cellular tower on the IIT campus? Why or why not?**

Yes.

**6. What would you suggest to include in the design of a new cellular tower?**

Not sure.

**7. What are your concerns of putting a cellular tower in the Bronzeville area?**

improve communications

### Appendix G: Turbine Summary

The two spots we could possibly put turbines is on the equipment building and the actual monopole. The helix wind turbines would be ideal for mounting on the monopole. Here are some specs of the different helix wind turbines:

#### Helix Wind:

This S594 model is the only helix model that can be mounted to a monopole. Here is a picture and some specifications of this model.

- Height: 19.8'
- Width: 4'
- Weight: 1400 lb
- Design Life: 30 years
- Energy Output: approximately 1000-1300 kW\*hr/year
- Cost: estimated to be \$16,000-17,000 including warranty



#### Aerotecture:

The Aerotecture wind turbines are made for rooftops. The 610V model specifications are listed below.

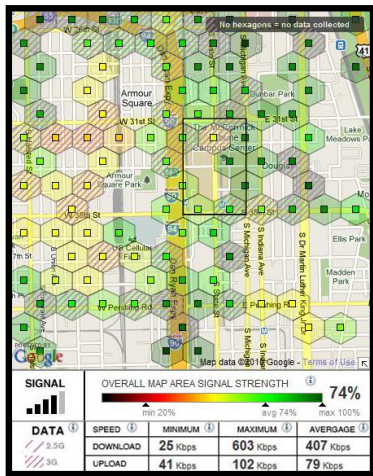
- Height: 10'
- Diameter: 6'
- Rotor Weight: 86 lb
- Energy Output: approximately 1500 – 2000 kW\*hr/year
- Cost: estimated to be \$15,000



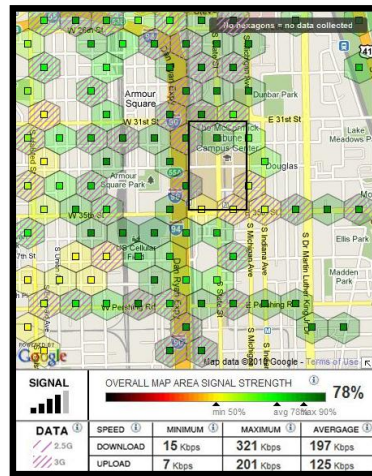
\*The energy output was found using the average wind in Chicago to be 11 mph.



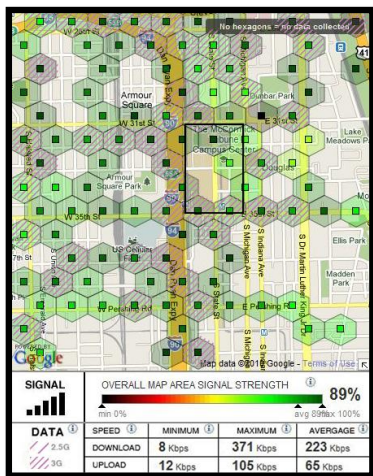
Appendix H: Site Analyses



AT&T Coverage Map



T-Mobile Coverage Map



Sprint Coverage Map



Verizon Coverage Map

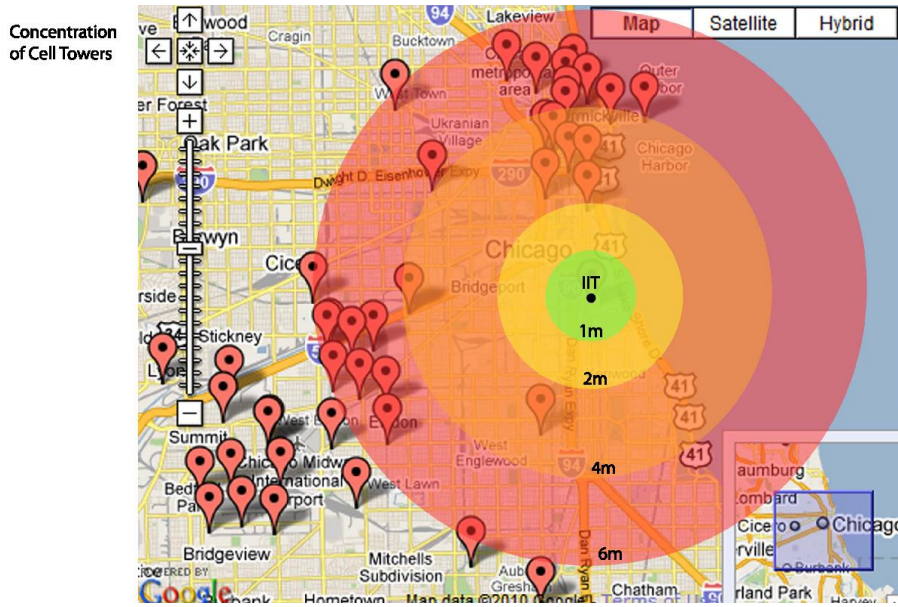
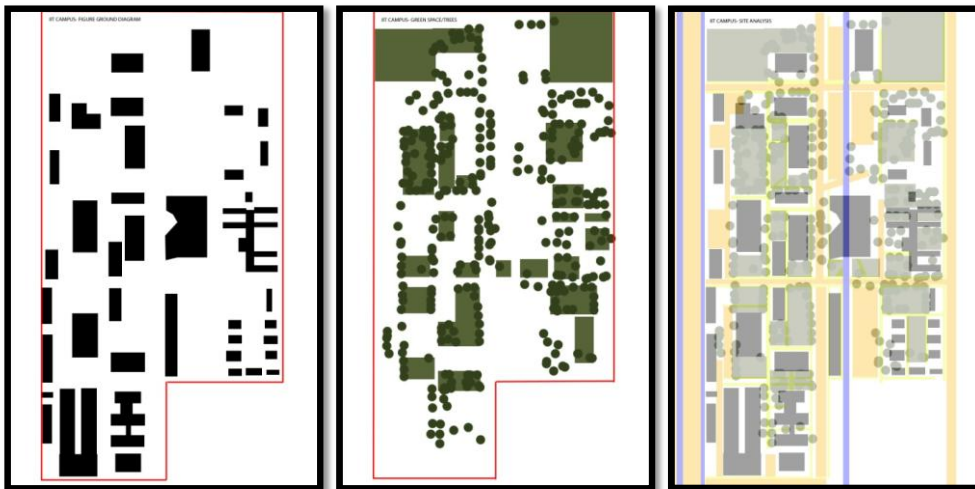
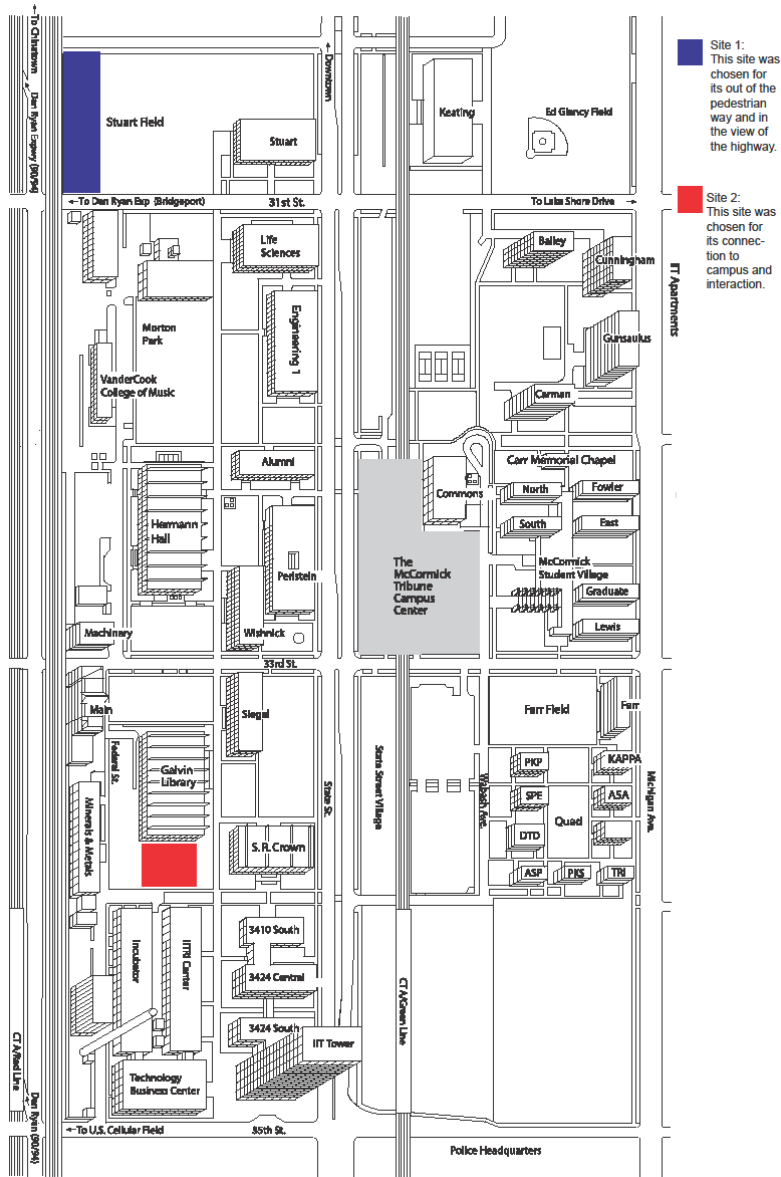


Diagram of Cell Tower Reception Relative to IIT Campus

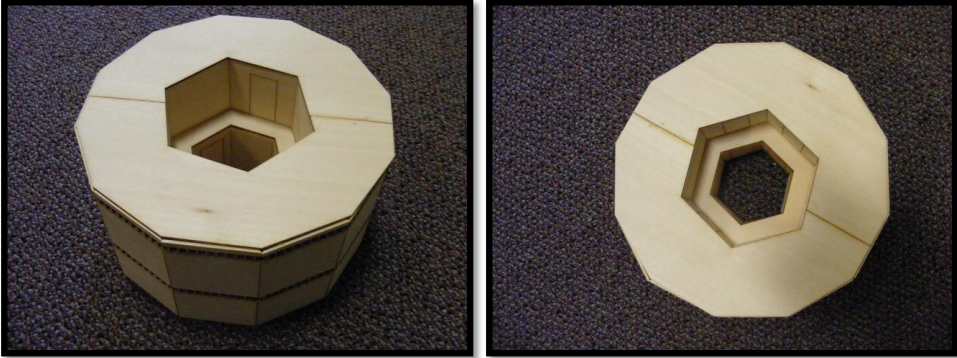


Site Analyses of IIT Campus

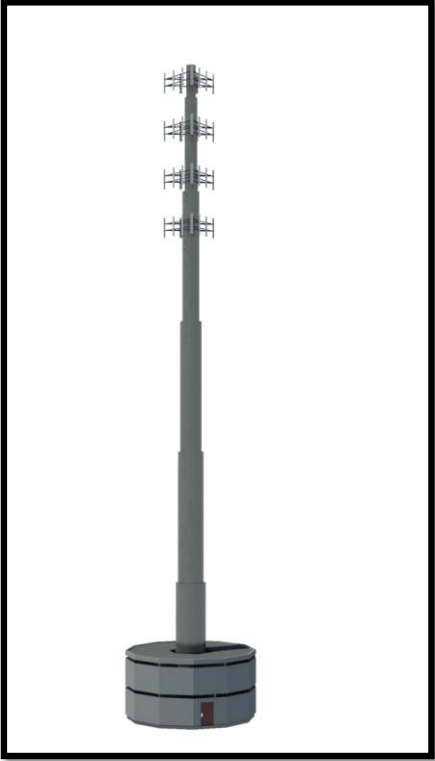


Future Site for Park Reimagined Housing  
Site Plan of IIT Campus

**Appendix I: Circle Building**



Circle Building Actual Model



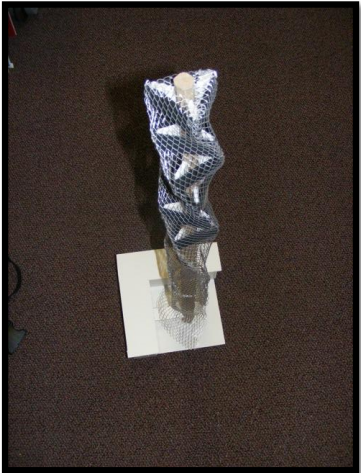
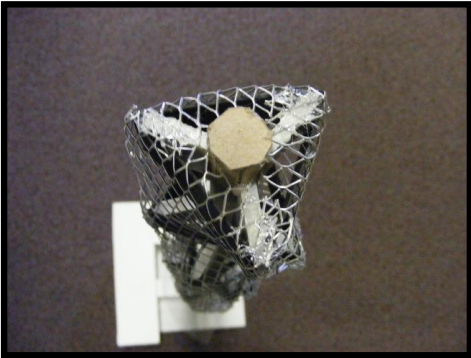
Circle Building Rendering

**Appendix J: Bell Tower Building**

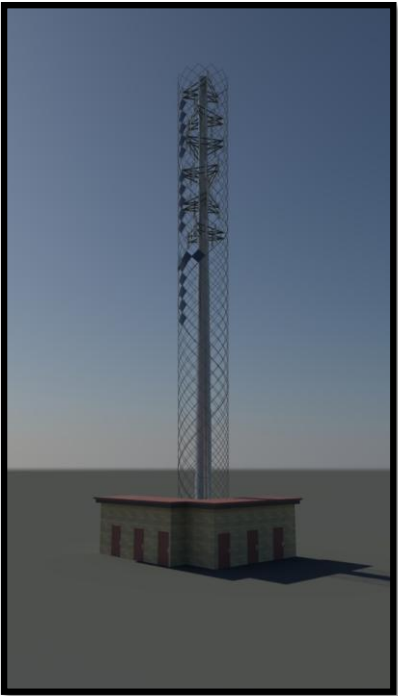


Bell Tower Rendering

**Appendix K: Sustainable Building**



Sustainable Design Actual Model



Sustainable Building Rendering