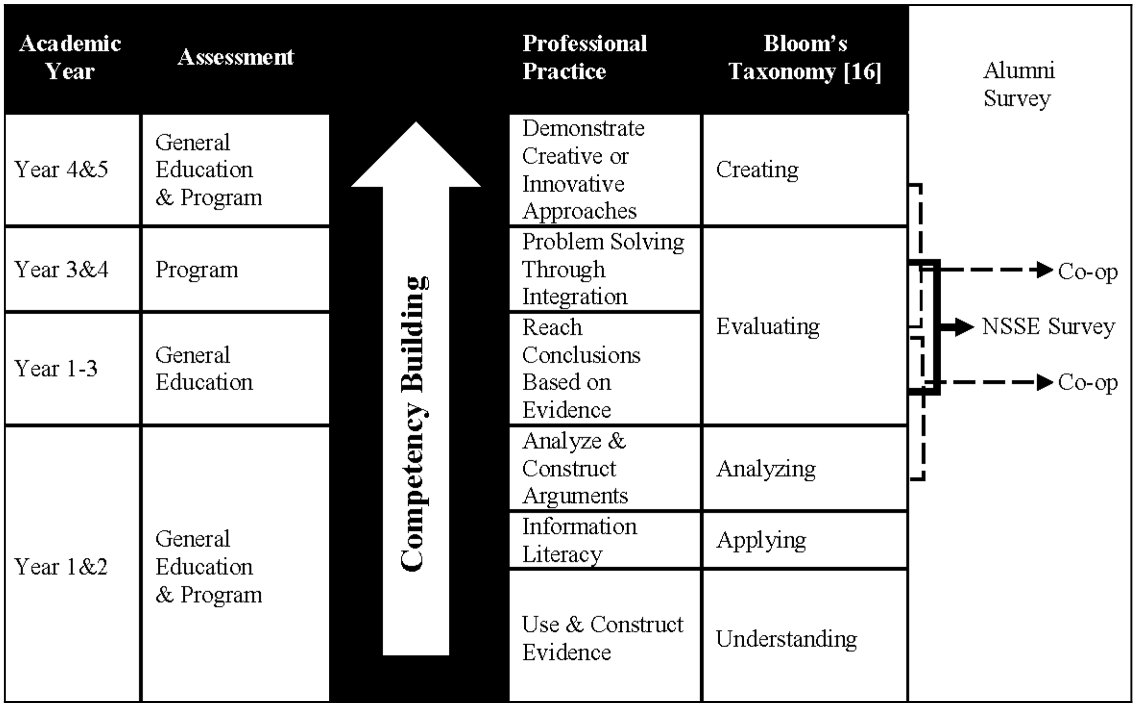
Summary of Examples of Best Practice Pedagogy Applied Critical Thinking at RIT

At RIT, critical thinking is taught and assessed across the student experience. Below is our map of the student learning outcome assessment by general education and program curricula.



Enclosed are a set of examples of applied critical thinking pedagogy. While the map above shows assessment points across the academic career, it is important to note that each of these student learning outcomes *together* support professional practice for students, and that that results in overall professional capability. Further, while the examples are noted within a particular outcome, a high quality assignment rarely focuses on a single capacity, and most examples exercise critical thinking in more than one way.

- Creative or innovative approaches:
  - GIS: Architectural Design Project (page 2)
- Problem solving through integration:
  - GIS: Greenhouse Gas Emission & Climate Change Assignment and Student Submission (page 15)
  - KGCOE: Logistics and Decision Making Case Study (page 22)
  - KGCOE: Optimization Case Study (page 32)
  - SCOB: Complex Problem Solving and Decision Modeling in Economics (page 39)
- Reach conclusions based upon evidence:
  - COB: Complex Problems and Uncertainty Reduction in Business Consulting (page 40)
  - KGCOE: Technology of the Day (page 41)
- Analyzing & Constructing an Argument:
  - KGCOE: Critical Analysis Assignment for Scholarly Articles (page 44)

ARCH-735 Architectural Studio IV: Integrative

Our comprehensive design studio is a good example of applying critical thinking across scales and disciplines. In this course students need to put together just about everything they've learned in the program into one comprehensive and integrative design. This is accomplished by taking on a semester long project in which the students and faculty member are assumed to be the developers. Every detail of the project must be analyzed in a micro sense but more importantly as an element of the whole. Some examples of the many steps are as follows:

- Students perform a zoning analysis in which they must glean the appropriate zoning requirements and then summarize them both in graphic and tabular form so as to inform different audiences, (such as zoning board, client, collaborating professionals). They must determine what to present and how to present it, i.e. they are not given a template of how to do this.
- Students perform a financial analysis of all aspects of the project. Again they are not given a template but rather start from scratch a spread sheet that takes into account development costs and a pro-forma. They must run various scenarios (that they come up with themselves) to ascertain feasibility of each.
- Once they arrive at the design phase they must utilize the data to substantiate their design decisions. They simply cannot propose a design because it's what "they like" or because it "looks good". It must make sense in a multiple-criteriate way.
- They conclude by proposing technical solutions for their design. For example they must select appropriate materials that make up the building's shell from literally thousands of choices and propose an assemblage that satisfies a dozen criteria for good building design such as keeping water out, keeping heat in, controlling solar radiation, etc.

By the end of the 15 week project, students have made literally hundreds, maybe even thousands of decisions both individually and as a member of a team to produce a project that is functional, durable, and pleasing to inhabit. This year's project statement is attached. Also attached is the grading rubric that gives a sense of the overlapping nature of the tasks involved in the design process. In this project there are 26 interrelated tasks that must be navigated on the way to the ultimate solution.

Professor Jules Chiavaroli

AIA, NCARB, LEED-AP

Architectural Design Project

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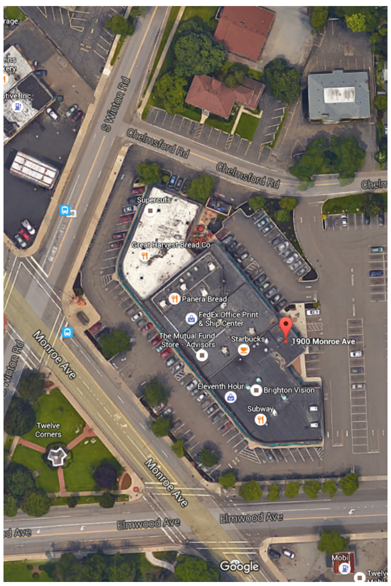
ARCH-735
Architectural Studio IV:
Integrative Design

12 Corners Redevelopment

1900 Monroe Avenue
Brighton, NY 14618



Course Instructor:

Professor Jules Chiavaroli, AIA
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Introduction

The Monroe Avenue corridor is arguably one of the most interesting in the area. Stretching from downtown Rochester, through the Town of Brighton, and ending in the Village of Pittsford it contains a wide variety of neighborhoods, retail centers, and open land. In fact it was the subject of a study conducted by the Community Design Center Rochester in 2011.

This project involves the demolition of an existing one-story retail building and replacing it with a multi-story, multi-use building. The project site is in Brighton, NY at the Town center known as Twelve Corners. The site is at the heart of the Monroe Avenue corridor.

As the designer/developer of the project, you will be completing a comprehensive and integrative design as outlined below.

Project Requirements

The following outline lists the requirements for the project. They are presented roughly in chronological order, however as is the nature of the design process, progress is made by more of a reoccurring cyclical process. More specific information for each of the requirements may be found on the following pages.

1. Pre-Design
    a. Zoning Analysis (team)
    b. Precedent Study (team)
    c. Financial Analysis (individual)
    d. Programming (team)
2. Schematic Design (individual)
    a. Concept development
    b. Performance modeling
    c. Integrative site/building design
3. Design Development (individual)
    - Site development
    - Building code analysis
    - Accessibility analysis
    - Energy analysis
    - Envelope development
    - Interior, vertical circulation, finishes development
    - Structural development
    - Selection of services and schematics

1a. Zoning Analysis

Given a site survey, your job is to complete a thorough zoning analysis. The goal of this analysis is to determine how the property can be maximized, in other words developed to its fullest potential. This includes the following steps:

1. Determine the zoning district in which the property falls.
2. Identify the allowable uses.

3. For the use selected determine the following at a minimum:
   - Minimum lot size
   - Minimum lot width
   - Minimum lot depth
   - Maximum building height
   - Minimum parking requirements
   - All setback requirements
   - Maximum lot coverage
4. Determination of building, parking, and open space configuration and dimensions
5. Identification of site and building characteristics and form.

Assume that variances will be obtained for deficiencies.

Deliverables:

Drawing sheet(s) that include the following:

1. Table comparing zoning requirements against proposed.
2. Site plan that graphically illustrates your findings based on the table above.

Resource:

- eCode 360
  http://www.generalcode.com/codification/ecode/library

1b. Precedent Study

Having completed a zoning analysis, your job now is to investigate case-studies similar to this project. i.e. complete a precedent study. The precedent study should inform your design by allowing you to see how the same problem was solved by others. It should include the following:

1. Project data: name, location, architect, size, typology, date
2. Plans, sections, elevations, images (photos or drawings)
3. Inventory of spaces including square footages and percentages
4. Relationship between spaces
5. Spatial shape and proportion
6. Subsystems: site, structure, services
7. General characteristic, design concept, problem solved

Deliverables:

1. A panel or panels professionally presented, that illustrate the components listed above. Some text would be desirable but consider presenting appropriate information in tabular form.

Resources:

- http://www.slideshare.net/cghfranck/aibd-first-tuesday-precedent
- http://moodle.unitec.ac.nz/pluginfile.php/318628/mod_resource/content/1/Precedent%20Slide%20Show.pdf

1c. Financial Analysis

Having completed a zoning analysis and precedent study, your job now is to create a financial analysis for the project. This analysis is the tool in the decision-making process that identifies the project's financial feasibility. The financial analysis includes the following:

1. An estimate of development costs and potential funding.
    - Land acquisition costs
    - Design fees
    - Permits and fees
    - Construction costs
    - Development expenses
    - Loan Interest
2. A projection of ongoing operational income and expenses - the proforma.
    - Rental income
    - Operation expenses

Deliverables:

A spread sheet financial analysis with two tabs that contain the following analyses:

- Development Costs
- Operating Projections or Proforma

Use the resource listed below (on myCourses) as a format and a guide to estimate values in your analysis. Except for input cells, all calculations should be executed by formulae.

Resources:

- Pages from Architect as Developer 2012 Booklet

1d. Programming

Having completed previous analyses, your job now is to create a program for the project. The program is the research and decision-making process that identifies the scope of work to be designed. The program should include the following:

1. Problem statement and establishment of project type
2. Research of the project type
3. Goals and objectives
4. Relevant information
5. Strategies
6. Qualitative and quantitative requirements
7. Summary.

Vision

This project involves the demolition of an existing one-story retail building and replacing it with a multi-story, multi-use building. But it is much more than that, this project is meant as a statement away from an automobile-centric community to a pedestrian-centric one. The driving force is that a trolly system will be built along Monroe Avenue and the park across from the property will be the main stop in Brighton. Twelve Corners will become a central attraction along this transit line and this project will lead the way in converting this community into a showcase of New Urbanism principles.

It is envisioned that the new building will be set at the property line to favor walk-in traffic. The ground floor will be a variety of retail spaces, pretty much what is there now. However there will be additional space because the goal is to make full use of the street exposure by filling the streetscape on Winton Road, Monroe Avenue, and Elmwood Avenue. Parking for the entire site will be moved to an underground parking garage beneath the building with only handicap parking at grade. The remainder of the site will be developed so as to connect the interior with the exterior, especially in summer. It is envisioned that one or two upscale bars/restaurants will occupy ground floor space and would utilize some of the site. Much of the rest of the site should be developed as public pedestrian space and as a transition to the small scale residential along Chelmsford Road.

Thus the building will act as a filter between the three busy streets and the quieter residential street behind. Some penetrations of the facade will likely be needed both for automobiles and to connect pedestrians with the developed site behind. Particular attention should be given to the flow of traffic into and out of the garage as well as service access to the ground floor businesses.

The number of stories should be either 3 or 4 depending on the financial analysis. If the project is feasible with 3 stories it should be designed so, if not consider a fourth floor. All upper floors will be office space since this is not an ideal location for residential. The upper story spaces will be a variety of offices, mostly professional services such as medical offices, law offices, insurance agencies, and perhaps even an architectural office. As part of the strategy to attract younger people to the Town, the style of the project should be contemporary.

Deliverables:

1. A professionally presented, written program with illustrations as necessary. The outline is flexible but should follow one, or be a combination of the formats presented in the following resources.

Resources:

- Cherry, Edith. *Architectural Programming*. PDF
- Hershberger, Robert G. Programming, An *exerpt from The Architect's Handbook of Professional Practice 13th Edition*. 2010.

2. Schematic Design

"During schematic design, an architect commonly develops study drawings, documents, or other media that illustrate the concepts of the design and include spatial relationships, scale, and form for the owner to review. Schematic design also is the research phase of the project, when zoning requirements or jurisdictional restrictions are discovered and addressed.

"This phase produces a final schematic design, to which the owner agrees after consultation and discussions with the architect. Costs are estimated based on overall project volume. The design then moves forward to the design development phase."[1]

Deliverables:

1. A complete set of schematic design drawings that fully describe and "sell" your solution. These drawings should include traditional views such as:
    - Plans (site and floor plans)
    - Sections (building and/or site profile)
    - Elevations and/or 3-D views.

1. AIA Best Practices. *Defining the Architect's Basic Services*. American Institute of Architects. 2007.

2. The solution should clearly demonstrate that it is evidence based and satisfies the requirements established in the program. Schematic diagrams, especially related to sustainability are key in demonstrating the effectiveness of your design. Schematics should include:
   - Wind rose and air flow study
   - Solar map with shadow study
   - Daylighting study for building interior(s)
   - Energy modeling study for optimal fenestration
   - A summative financial analysis
   - An updated zoning analysis.
3. A Means® square foot cost estimate.

Resources:

- Revit, Vasari, Ecotect, Lighting Analysis for Revit, Green Building Studio
- http://www.aia.org/aiaucmp/groups/secure/documents/pdf/aiap026834.pdf
- https://www.rsmeans.com/login.aspx?returnurl=/account.aspx

3. Design Development

"Design development (DD) services use the initial design documents from the schematic phase and take them one step further. This phase lays out mechanical, electrical, plumbing, structural, and architectural details.

Typically referred to as DD, this phase results in drawings that often specify design elements such as material types and location of windows and doors. The level of detail provided in the DD phase is determined by the owner's request and the project requirements. The DD phase often ends with a formal presentation to, and approval by, the owner."[1]

Deliverables:

In the design development phase most of the traditional technical drawings are produced to a fairly substantial level: floor plans, sections, and elevations with full dimensions. These are completed in all disciplines; architectural, civil, structural, and services.

Documentation of your work is critical just as it is on the job. Your work will become part of the project notebook that is read by others on the project team. It should therefore be concise, accurate, and written/documented in a loose research format.

The instructor will serve as the project architect and you as his associate. You will take the lead in determining the specifics of the project and he will guide you.

The following assumptions are to be considered:

- Design improvements are always part of the process and are usually part of this phase of the project, as the name implies *design development*.
- All materials and methods of construction must meet code and zoning requirements.
- Site design is to be included in the work.

The following documentation is required for this project:

GENERAL

1. Building code analysis. Chapters 1-10 of the building code that identifies use and occupancy, type of construction/area allowed, area adjustment for sprinklers, fire resistive construction ratings for major components, interior fire ratings, fire protection systems and egress.
2. Energy analysis with COMCheck (HVAC and lighting)

3. Accessibility analysis. The major aspects of accessibility codes have been met (ANSI and ADA). Show that the site design and building designs are in compliance.
4. Sustainability features diagrams
5. Cost comparison of select building assembly systems
6. Outline specifications for select building assembly systems

ARCHITECTURAL (A series drawings)

1. Architectural Floor Plans (first and typical floors) including a keying of wall types. Indicate wall materials, finalize and show major dimensions (overall, offsets, openings, interior walls). Show all built-in components including location of incoming utilities; electrical panel, water service entry with hot water heater, and mechanical equipment. All doors and windows should be accurate in scale.
2. Room Finish Schedule (typical floor).
3. Door Schedule (typical floor).
4. Wall sections at 3/4" = 1' - 0" and details at 1-1/2" = 1' - 0". Determine sub-structure. Design and size the foundation. Determine super-structure; wall construction, roof/ceiling construction, and floor construction noting materials and sizes for each. Perform COMcheck™ to confirm design.
4. Enlarged stair plans and section (1/2" scale).
5. Reflected Ceiling Plan (typical floor).

CIVIL SITE combine as appropriate (C series drawings)

Site plan(s) including roads, parking, and landscaping (including patios, decks, etc.). All materials and buildings should be illustrated and noted as to what the material is and indicating what is existing, what is existing to be removed, and what is proposed. The new building should be located on the property, i.e. dimensioned as to where to be placed but not building dimensions themselves. All grading should be resolved with existing contours, new contours, and appropriate spot elevations. All site improvements are to be dimensioned. The following may be combined into fewer than four separate drawings as long as readability is not compromised.

1. Site improvement plan
2. Landscaping plan
3. Grading and storm water management plan
4. Site utility plan showing services from street to building and back out again

STRUCTURAL (S series drawings)

1. Foundation Plan and Detail(s)
2. Framing plan (typical floor) with members selected and noted. Create structural plans for each floor, assume steel frame construction. Select one bay of the design and perform structural calculations to size beams, columns, and connection details within the bay.

MECHANICAL (M series drawings)

1. Selection of main mechanical systems and supplemental systems
2. Schematic plans showing routing of HVAC system

ELECTRICAL (E series drawings)

1. Schematic plans showing routing of electrical system including electrical panels
2. Lighting layout

PLUMBING (P series drawings)

1. Schematic plans showing routing of:
    - Water supply
    - Waste
2. Roof plan showing location and size of roof drains and leaders to site drainage system

FIRE PROTECTION (FP series drawings)

1. Analysis of required and/or recommended fire protection systems and illustration of such on drawings.

For all services above (M, E, P, and FP), identify and schematically represented on a site utility plan, on the floor plan, and in the section: water supply and waste removal, electrical supply, with interior and exterior lighting, selection of type of HVAC system, storm water system including roof leaders, grading, catch basins, etc.

For small format documentation create a project notebook (3-ring binder) subdivided into the categories noted on the attached rubric. Keep all your work in the notebook with the most recent in each section on top. Keep the master copy of the Grading Rubric in the cover of the notebook to be used as a record of approval.

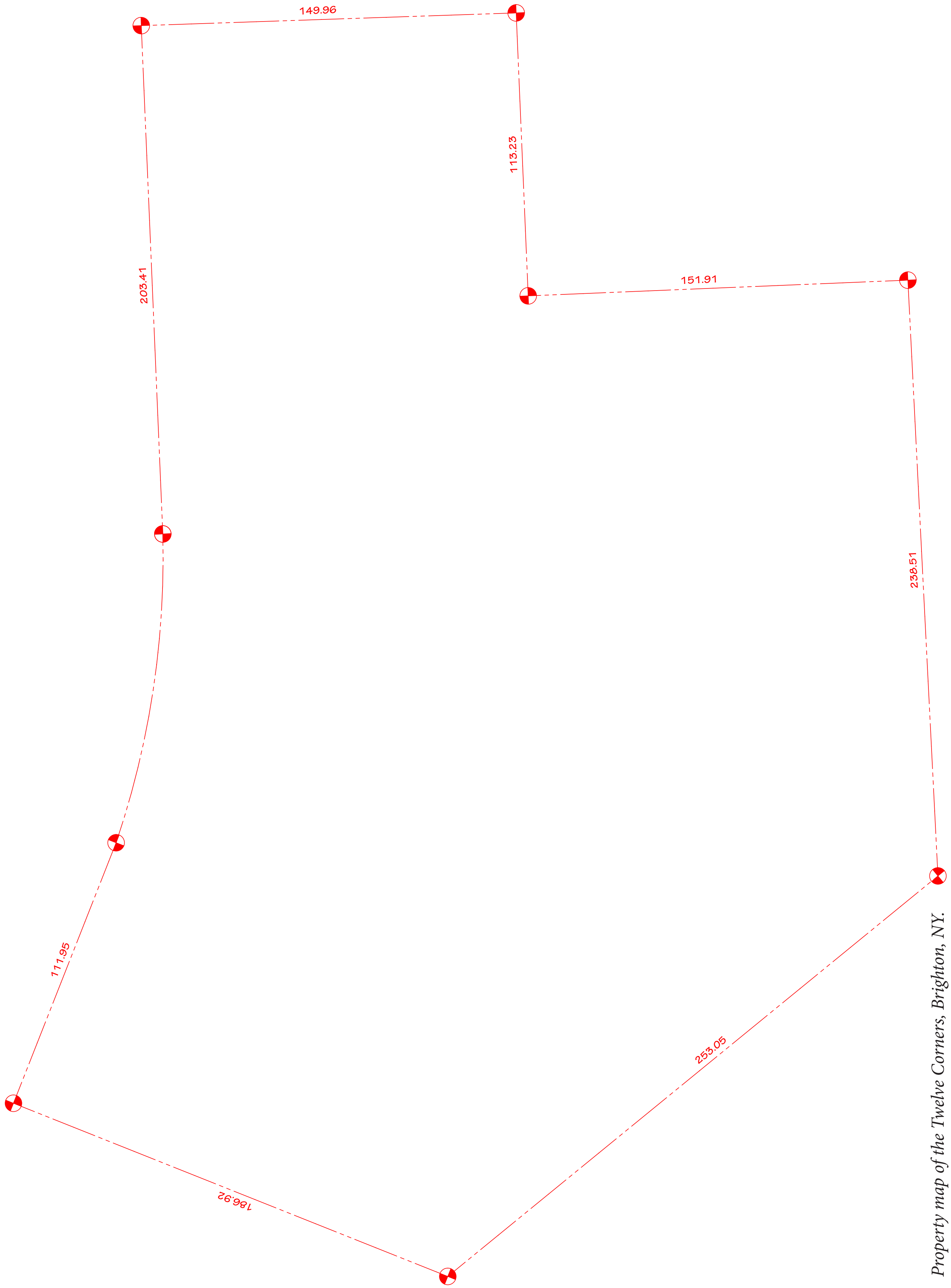
All documentation may take a variety of forms including plans, sections, and elevations as well as notations from references, sketches, tables of information, marked-up copies of reference materials, printed reports, calculations, etc. Essentially your documentation should provide evidence that substantiates each of your decisions during the design development phase. While you are welcome to work together, each student must submit his/her own documentation.

Resources:

- Allen, Edward; Iano, Joseph. *Fundamentals of Building Construction: Materials and Methods*. Sixth Edition. Wiley. 2014.
- American Institute of Architects. *Architectural Graphic Standards, Eleventh Edition*. 2007.
- Ching, Francis D.K.. *Building Construction Illustrated: 5th Edition*. Wiley. 2010.
- Building Code of New York State. http://publicecodes.cyberregs.com/st/ny/st/
- Building Energy Code, US Department of Energy. https://www.energycodes.gov/comcheck
- Americans with Disability Act. http://www.ada.gov/2010ADAstandards_index.htm
- American Institute of Steel Construction. *Steel Construction Manual, 14th Edition*. 2011
- Manufacturer's catalogs for steel joists, steel decking, and precast concrete plank

Area map of the Twelve Corners, Brighton, NY.

Contour map of the Twelve Corners, Brighton, NY.



Property map of the Twelve Corners, Brighton, NY.

Project: Twelve Corners Redevelopment

Grading Rubric

ARCH-735
Architectural Studio IV: Integrative Design

Master of Architecture Program • Rochester Institute of Technology
Professor Jules Chiavaroli

Student:

	Submission 1	Submission 2	Submission 3	Submission 4	Submission 5	Submission 6 May 18
A. Pre-Design Analysis						
1. Zoning	1					
2. Precedent Study	2					
3. Financial Analysis	3					
4. Programming	4					
B. Schematic Design						
1. Concept		1				
2. Performance Modeling		2				
3. Comprehensive Design		3				
C. General Design Development						
1. Building Code Analysis			1			
2. Feasibility Study			2			
3. Component Cost Comparison				1		
4. Outline Specifications				2		
5. LEED Analysis					1	
D. Civil/Site Design Development						
1. Site improvement plan			3			
2. Grading and storm water management plan			4			
3. Landscaping plan			5			
E. Architectural Design Development						
1. Wall construction with openings			6			
2. Dimensioning			7			
3. Built-ins, notes, material indications			8			
F. Structural Design Development						
1. Structural Design				3		
2. Foundation Plan and Detail				4		
3. Framing Plans				5		
G. Services Design Development						
1. Selection of HVAC systems				6		
2. Schematic plans of main HVAC system					2	
3. Schematic plans of elecrical system					3	
4. Schematic plans of pumbing systems					4	
5. Schematic plans of fire protection systems					5	
	4	3	8	6	5	26

Greenhouse Gas Emission & Climate Change Assignment
ISUS.702.01
Fall 2015

Homework #6

Due Date: September 29, 2015

Reading: S. Solomon *et al*., "Irreversible climate change due to carbon dioxide emissions," *Proceedings of the National Academy of Sciences,* **106**:1704-1709 (2009).

Homework Assignment #6: Assume the world continues on the current trend of widespread fossil fuel combustion and, as argued by Solomon *et al*., atmospheric CO_2 affects global climate with a 1000-year time constant. As Senior Sustainability Scientist for the White House Office of Science & Technology, how would you propose addressing the duel sustainability objectives of greenhouse gas emission reduction and climate change adaptation. Your plan must comprehend environmental, economic and social considerations.

Kyle Parnell
Fundamentals of Sustainability Science
ISUS.702.01
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As a bachelor of arts in English literature, I am morally obligated to highlight that two sentences ago, the word duel (a match between two opponents, commonly with swords or pistols) was used in place of the word dual (comprised of two). 9.5/10.

Solomon *et al.* conclude that the largest consequences of carbon dioxide emissions, even after their cessation, will be global temperature increase, changes in precipitation systems, and sea level rise in the range of 0.4-1.9 meters (1705-07). Given that *all* of these consequences are caused by atmospheric CO_2, it is imperative to make reduction of CO_2 emissions via initiatives to move away from dependence on fossil fuel a central goal of the Administration. This involves considerable investments in sustainable energy technology research as well as carbon capture and storage technologies to curb our current rates of emission. However, because C02 is millesimally tenacious, these consequences will continue to be wrought even if complete elimination of emissions is accomplished. It must therefore be recognized that human societal adaptation to these inevitable effects is a necessary factor in preserving the welfare of the American people.

As Senior Sustainability Scientist, Triple S, it is my sincere belief that reduction of emissions in effort to move towards complete elimination is ultimately paramount to mitigating the overall damage to American society caused by anthropogenic climate change. Adaptation, while important to preserving life and property, does little to alter the effects of human activities on the natural environment, and must therefore be relegated to our second-place priority. In order to achieve reduction of carbon dioxide emissions, we must focus first on mitigating future CO_2 outputs by mandating carbon capture and storage systems for all fossil-fuel burning power stations in the U.S. According to the Center for Climate and Energy Solutions, the costs of implementing CCS systems into electricity production in the U.S is economically viable:

Table 1: Levelized Cost of Electricity for New-Build Power Plants with and without CCS

Power Plant Type (new-build)	Average LCOE without CCS ($/MWH)	Average LCOE with CCS ($/MWh)
IGCC	97.8	141.7
PC	75.0	137.1
NGCC	74.7	108.9

Table 2: Cost of CO_2 Capture and Transportation for Various Industrial CO_2 Sources

Industrial CO_2 Source	Cost of CO_2 Capture and Transp. ($/Metric ton)
Coal and biomass-to-liquids	36.10
Natural gas processing	36.29
Hydrogen plants	36.67 to 46.12
Refineries (Hydrogen)	36.67 to 46.12
Ammonia plants	39.69
Ethanol plants	42.15
Cement plants	81.08

Source: http://www.c2es.org/technology/factsheet/CCS

Clearly, the cost of CCS in electricity production is more than manageable. While CCS is by no means a sustainable technology, it is a transition technology that moves us closer to carbon elimination, and, at present, satisfies the economic requirement for approaching sustainability. Further, communities dependent on fossil fuel electricity production as employers will be able to keep their jobs for the time being, and new work opportunities will become available as CCS systems are implemented. This keeps social backlash at a minimum and thus satisfies the social requirement for approaching sustainability.

In addition, we must explore options for monumentally increasing our use of sustainable, renewable energy sources. This is an effort to move away from fossil fuels so that we may achieve minimization and, eventually, cessation of carbon emissions—a necessary step in sustainable evolution if we are to meet even the *best*-not-great case scenario proposed by Solomon *et al.* To accomplish this, we must first employ existing technologies at a larger scale, using job creation and environmental cost savings to offset the comparatively higher initial costs of such technologies. The preferable example is solar technology. While still reliant on rare earth elements that at present necessitate the use of fossil fuels and harmful extraction processes, solar energy systems offer the possibility of a one-time energy and materials investment to produce electricity with little further investment over a significant lifecycle. Though solar energy is not nearly a 100% efficient system, some scientists believe that it is a vastly underutilized technology that offers incredible benefits. Indeed, with all the sun exposure over vast, empty areas of earth's surface, it seems reasonably possible to harvest significant amounts of energy we currently let go to waste.

This map from the Land Art Generator Initiative demonstrates estimates of the total area of solar panels that could power the *entire world*:

Source: http://www.techinsider.io/map-shows-solar-panels-to-power-the-earth-2015-9

SURFACE AREA REQUIRED TO POWER THE WORLD

WITH ZERO CARBON EMISSIONS AND WITH SOLAR ALONE

www.landartgenerator.org

BOXES TO SCALE WITH MAP

- 1980 (based on actual use) 207,368 SQUARE KILOMETERS
- 2008 (based on actual use) 366,375 SQUARE KILOMETERS
- 2030 (projection) 496,805 SQUARE KILOMETERS

Required area that would be needed in the year 2030 is shown as one large square in the key above and also as distributed around the world relative to use and available sunlight.

- Areas are calculated based on an assumption of 20% operating efficiency of collection devices and a 2000 hour per year natural solar input of 1000 watts per square meter striking the surface.
- These 19 areas distributed on the map show roughly what would be a reasonable responsibility for various parts of the world based on 2009 usage. They would be further divided many times, the more the better to reach a diversified infrastructure that localizes use as much as possible.
- The large square in the Saharan Desert (1/4 of the overall 2030 required area) would power all of Europe and North Africa. Though very large, it is 18 times less than the total area of that desert.
- The definition of "power" covers the fuel required to run all electrical consumption, all machinery, and all forms of transportation. It is based on the US Department of Energy statistics of worldwide Btu consumption and estimates the 2030 usage (678 quadrillion Btu) to be 44% greater than that of 2008.
- Area calculations do not include magenta border lines.

LAND ART GENERATOR INITIATIVE

The total is an area roughly the size of the country of Spain. While initially this seems like an impossible area, the number represents a cumulative area. If solar panels could be reasonably implemented on a local scale (and they can be), cumulative area may be able to equal the necessary levels. These estimates predict that with the given area covered entirely in solar panels, an existing technology, we could achieve 100% electricity independence. Total area required for 100% solar energy production in the U.S. could fit inside open, unpopulated, non-arable land that makes up western desert areas.

It is my professional opinion as Triple S that 80% of available resources should be allocated to these mitigation efforts. Solomon *et al.*'s predictions suggest a continuation of adverse effects even if we achieve complete cessation of emissions. Should emissions continue, even at a decreasing rate, negative effects of climate change can be expected to intensify. As this is not unlikely given American culture's resistance to change and especially to reason, we must divert some resources to adaptation efforts. The most threatening consequences are sea level rise and precipitation changes. In order to preserve human life, we must consider addressing these issues in two ways: 1) reconfiguring population distribution in coastal areas and 2) mitigating unnecessary and wasteful fresh water usage to ensure availability for direct human consumption for the purpose of sustaining life.

The first goal can be accomplished by creating new infrastructure projects to build seawalls, storm channels, and drain systems that can accommodate sea level rise, as well as advocating for the migration of densely populated coastal communities to a safer distance inland. While this may present significant social resistance, it is a sociologically observable trend that people follow jobs. Thus, if employment opportunities are created inland, populations will geographically reconfigure to follow those jobs. Creating solar technology firms and infrastructure material construction jobs at inland sites may help encourage the migration away from threatened coastal areas.

Second, fresh water usage must be curbed as increasing drought is to be expected. To accomplish this, golf courses and industrial-scale agriculture operations must be held responsible for the full cost of irrigation. One solution to this may be to mandate that such organizations privately purchase and operate desalination systems that can provide irrigation water from effectively infinite stocks of ocean water. This would reduce stress on natural aquifers and lakes, leading to preservation of associated ecosystems and the ability to adapt to decreases in rainfall without depleting scarce resources.

Adaptation strategies are little more than processes of stalling human losses. As they cannot be considered permanent solutions—sea walls will fail, farming lands will dry up, etc.—they cannot be considered static costs. Once resources are put into adaptation, we may buy a few more years, but will ultimately have to continue to put more and more resources into adaptation as effects continue to worse. As this will be the more expensive option in the long run, I advise that only 20% of available resources be allocated to this area.

The benefits gained from adaptation are simply too short-term and short-lived to warrant significant investment. In contrast, investment in movement toward absolute sustainability yields much higher returns in the form of saved costs from future climate change damages, since the magnitude of negative effects may curtailed by present efforts to cease carbon dioxide emissions. Environmentally, sustainable energy systems and carbon sequestration are clearly the top choices. Economically, they are expensive, but these costs can be offset, in conjunction with the effects of social backlash from fossil-fuel workers, by creating new jobs in sustainable energy technology development and the construction of the necessary infrastructure to support those energy systems.

Logistics and Decision Making Case Study:

DEALING WITH THE BUG IN THE CLASSROOMS: PLANNING FOR A PANDEMIC

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Abstract

In 2009, public and private organizations were forced to consider how the circulation of a new and potentially lethal infectious disease, the H1N1 flu virus, would affect their day-to-day activities. The virus started circulating in the spring of 2009 and in a matter of months it had already spread all over the world. Similarly, to what happened in the deadly 1918 Spanish Influenza, it especially affected young adults, pregnant women, and people with weak immune systems. Universities, colleges, and school districts were among the organizations that had to design and implement response and mitigation plans that would not only protect their students, but that would avoid any disruption to the academic calendar while considering limited available resources. The following two-part case study describes some of the challenges faced by Rochester Institute of Technology (RIT), a private university in upstate New York, in dealing with H1N1, and gives students the opportunity to apply quantitative analysis to help the university develop a preparedness plan to deal with future pandemics.

Note of caution for the readers

Although the author has used real data and figures to describe the evolution of the H1N1 in the USA and the challenges faced by RIT, many of the dialogs and thoughts attributed to the characters in this document are fictional, and are designed by the author to describe challenging situations that academic administrators may have to deal with during a pandemic. As a consequence, the data about RIT, the characters of this paper, and H1N1 contained in this case study should be used only for instruction.

H1N1: The First Global Pandemic of the 21st Century

In April of 2009 the H1N1 influenza outbreak was first detected in Mexico, when hospitals were overwhelmed by an unexpected number of patients with influenza-like illnesses (ILI), whose health quickly deteriorated into a fatal pneumonia. Moreover, in less than a month, Mexico reported more than 2000 confirmed cases of this new type of flu [1]. The unusual flu virus rapidly spread over the world and in a period of just 2 months, 74 countries reported over 28,000 confirmed cases, and 144 deaths [2]. In June 11, 2009 the World Health Organization (WHO) declared the state of a global pandemic.

The public reaction to this pandemic flu was intense. Although there had been discussions about the effects of a potentially deadly flu pandemic since 2005 (the avian flu, H5N1), many governments and organizations were not prepared for dealing with the pandemic and did not have mitigation plans in place. Additionally, even in countries having such plans, their implementation details and their effect on the day-to-day activities of public and private organizations were unclear or inexistent. It was only when the H1N1 pandemic attracted media attention that serious discussions about the consequences of the pandemic on everyone's daily routines began.

At the early stages of the pandemic, public health officials warned that available seasonal flu vaccines would not help to protect individuals from contracting the new H1N1 virus, given that the new virus strain had not been present among humans in the past, and because the available flu vaccine targeted three other types of flu strains. Therefore, a new vaccine had to be developed from scratch as soon as the new virus was identified and characterized. Experts suggested that such a development would take no less than 6 months [3].

To control the effects of the influenza pandemic, public health officials also had in their arsenal two types of antiviral medication (Tamiflu© and Zanamivir©) [4], which could be used to mitigate the mortality and morbidity (i.e. the lethality of the disease and its health consequences) of the H1N1 virus (Antivirals reduce the progression of the virus in infected individuals and help patients recover faster.) However, in the Spring of 2009, the global supply of antivirals was insufficient to treat all those who could be infected by the H1N1 in the months to come [4]. Antiviral production, although faster than vaccine production, could not be increased to satisfy the expected antiviral demand within the first 6 months. Furthermore, at the time, there was high uncertainty about H1N1, and hence the resulting demand for antivirals.

The H1N1 virus had several peculiar characteristics. Although the virus was highly infectious, it was fortunately less lethal than expected. By Spring 2010, it had claimed fewer lives than the typical seasonal flu strains. Every year, in the United States an average of 30,000 individuals die as a consequence of seasonal flu, while between April 2009 and May 2010 the global number of deaths resulting from H1N1 as reported by the World Health Organization (WHO) was approximately 18,000 [5]. In addition, when the flu outbreak started, public health officials expected that H1N1 would follow the life cycle of seasonal flu, ending during the summer time. However, in 2009 the number of people infected with the virus continued to increase during the summer months [4].

The infectious cycle of influenza viruses, including H1N1, starts with the infection of a susceptible person, who will typically incubate the virus for 2-4 days without noticeable symptoms before showing flu-like symptoms. An infected individual is infectious between one day before the onset of symptoms until 5-7 days after the onset [6].

About Rochester Institute of Technology (RIT)

RIT is a privately endowed, co-educational university in suburban Rochester NY. RIT is well-known for the quality of its STEM education, its co-op program, and for having more than 1,200 deaf and hard of hearing students supported by RIT's National Technical Institute for the Deaf. RIT's student body in 2013 was 18,292 students (15,410 undergraduates, and 2,882 graduates). Funded in 1829, the university adopted its current name in 1944. Until 2012, RIT's academic calendar was organized in four 10-week quarters: Fall (Aug-Oct), Winter (Nov-Mar), Spring (Mar-May), and Summer (June-Aug) quarters. RIT has one of the largest cooperative education programs in the world, placing more than 3,500 students in more than 5,500 co-op assignments every year. More information about RIT is available at www.rit.edu/overview/ .

A. RIT and the Pandemic

In May 2009, RIT put together a special Influenza Committee (IC) appointed to deal with the possibility of an H1N1 crisis in campus. The committee comprised of the medical and administrative directors of the Student Health Center, a faculty with previous logistics expertise, a member of the county's public health department, members of the University’s Registrar office, and a representative of campus food services. The committee reported weekly to the Provost with an overview of the national, state, and county pandemic status, information about any potential threats to campus life, and the details on the execution of any action plans. The committee's work began almost a month after the beginning of the pandemic. By Fall 2009, the committee was required to report twice a week.

Table 1 in the Appendix describes the evolution of patients with Influenza-Like-Illness (ILI) reported in RIT during 2009.

In the Spring of 2009, health authorities expected that the pandemic receded and perhaps be contained during the summer season, but H1N1 proved to be unusual and continued to infect young adults at higher rates than those for seasonal flu. During the Summer of 2009, public health authorities and vaccine producers made public two positive news. First, they clarified that a single vaccine dose would provide full protection against H1N1 instead of the two doses originally planned [7]. Second, vaccine producers confirmed that Phase III tests were successful and that the H1N1 vaccine would be ready for distribution as early as October, 2009 [4].

Once the vaccine became available during the Fall of 2009, it became clear that local health officials were not ready to deal with the distribution of vaccines. For example, RIT placed an order of 13,000 vaccine doses, which were freely provided by the county health officials, but only received an initial batch of 6,000 doses. There was uncertainty regarding when the remaining doses would be provided. In contrast, smaller academic institutions in the area received more doses than needed. For example, a small private college in Rochester enrolling less than 3,000 students received more than 5,000 doses.

Additionally, a challenge for schools planning to provide immunization to their students and faculty was their inability to know if their students and faculty had already been vaccinated outside campus. Due to supply restrictions, public concern, and the fact that college students were considered a population at risk, many students and faculty took advantage of other opportunities in town to get vaccinated.

The challenge of matching vaccine demand with vaccine supply proved to be more complex than authorities and vaccine manufactures expected. The combined effect of coordination problems and the backlog of vaccine orders resulted in a large number of unused vaccines by the end of the summer 2010. In the United States alone, it is estimated that nearly 70 million purchased doses were left unused [8]. By August 2010, the H1N1 pandemic was officially contained, and RIT received the last number of doses that completed its original request, which were no longer needed.

B. Recommendations of the Influenza Committee during the 2009 pandemic

The main challenge to the IC's work was the uncertainty related with the behavior of the flu and its impact on campus life. In the early stages of the pandemic, there was tremendous speculation about how severe the flu really was. It was not clear if it would develop into a Spanish flu-like pandemic, which reported between 50 -100 million deaths worldwide [9], or if it would result in just a severe type of seasonal flu (with nearly 30,000 deaths per year in the USA). Since there was no vaccine for H1N1, the committee did not know if students would need to be vaccinated once or twice, and how spread out those immunizations had to be provided to ensure full protection. More importantly, it was not clear how lethal the flu strain was. Additionally, there was general concern about the efficacy and safety of the potential vaccines. For example, the media and blogs had speculated that the development of a new vaccine needed to be expedited, and because of that producers might not have enough time to do extensive safety tests. Sensationalist media (Glenn Beck, Oct 3, 2009) speculated that unlikely vaccine side-effects, such as those occurred during the 1970's pandemic linked to Guillain-Barré syndrome could re-occur with the H1N1 vaccine [10].

Local health authorities had recommended that RIT's Influenza preparedness plans deal with the consequences of infected individuals on campus until immunization was effectively available for most students and faculty. Under such circumstances, the committee faced the risk of planning activities that would have been unable to deal with the actual outbreak in campus, or that would have been excessively disruptive on the day-to-day activities. Once appointed, the IC wanted to know the most adequate actions to follow for dealing with an uncertain event within the following 8 months.

During their tenure, the committee established and coordinated plans that covered eight areas: (1) campus hygiene, (2) medicine and vaccine procurement, (3) confinement of infected students

(4) public relations, (5) capacity planning of the medical center, (6) class disruption, (7) food and wastage logistics during the pandemic, and (8) class suspension. A complete description of these areas is provided below.

1. Campus hygiene:

Influenza is an airborne transmitted disease that can live outside the human body between 2 to 12 hours depending on temperature conditions and the material of a contaminated surface. An individual could become infected with the virus by sharing fluids with an infected individual. Such exchange could occur through direct exchange of body fluids, by breathing air that contains infected saliva droplets, or by bringing the infected droplets deposited in a contaminated surface to one's mouth and nose. Accordingly, the Influenza Committee was convinced that hygienic practices would be crucial to contain the spread of the disease in RIT, and that such practices would constitute the most cost-effective intervention. Hygienic recommendations included installing hand disinfectant dispensers in highly transited areas of campus. Additionally, the IC started an aggressive campaign to increase awareness about the importance of sanitation to control the virus. Emails, group messages, posters, and classroom time were used to emphasize the need for adopting good preventive practices, such as washing hands, sneezing in your elbow, and avoiding spitting. The IC also recommended increasing the frequency at which doorknobs, computer keyboards, and bathrooms were sanitized.

2. Medicine and vaccine procurement:

The IC recommended that the university's health center set up a stockpile of cold packages (i.e., analgesics, cough syrup, and decongestants) that could help diagnosed individuals alleviate their flu symptoms. Although antivirals (Tamiflu and Zanamivir) were recommended to treat symptomatic patients, universities were not allowed to build their own antiviral inventory. Antiviral producers had reported a backlog of orders and were given priority to state and national health care systems. Any needed antivirals would have to be externally supplied or be requested by the student's care provider. The main challenge in setting up the stockpile of cold packages was determining the number of packages to order, and where to store them. Additionally, the committee recommended that RIT established an inventory of ancillary supplies (e.g., masks and latex gloves) for at least 3,000 individuals.

3. Confinement of infected students:

Almost 8,000 students lived in some of the available campus housing options. Most undergraduate students stayed in dorms, where they shared a room with at least one additional student. One of the main problems faced by the Influenza Committee was to determine how to proceed when a student was diagnosed with influenza-like symptoms. For example, if a symptomatic student could not leave campus to recover at his family's home, he or she needed to be isolated for 4 days. If the student were to stay in his/her own room, the main concern was what to do with the patient's roommates. If roommates decided to stay in the room, they would have been unnecessarily exposed to the virus. If the roommates temporarily move out of the room, they could have been potentially infectious to others, as the roommates could have been already infected but not showing symptoms. Moreover, if the committee recommended to isolate infected individuals and their roommates, the committee had to establish who qualified for isolation, where to accommodate students, the maximum number of students to accommodate, as well as an estimated budget to cover for such plans.

During 2009, recommendations were constantly revisited based on the evolving available information. Initially, the official policy was to recommend infected individuals to recover at their parent's home, but if a patient was too sick to travel or if the family was too far from RIT, the student could have remained in campus. The patient's roommates were given the option to stay in the room if they wished and were asked to take extreme hygienic precautions for four days, and to wear a supplied mask and goggles at all times.

For the H1N1 in 2009 an exclusive isolation area was not necessary, but for more infectious and morbid strains, the university may have needed an area to assist infected students until they ceased to be contagious.

4. Public relations:

The IC's focused on ensuring that the RIT community remained well informed and educated on practices that could have reduced the risk of spreading the disease. Moreover, the committee was careful not to overwhelm the public with general information, and maintained an easy-to-follow repository of RIT-relevant news. The committee set up a general web page which provided access to forums and discussion groups, and where medical personal and university authorities could clarify issues of general concern. Additionally, there was at least one information session per month in which questions could be posed directly to administrators and public health officials. When the influenza vaccine became available, the communications strategy focused on informing students about how the vaccination clinics would work, and what the public could do to facilitate the vaccination process.

5. Capacity planning:

In 2009, one of the main concerns of the university authorities was whether the Student Health Center had enough capacity to assist students developing influenza-like symptoms. The center had 2 doctors and 7 nurses in staff and was open on average 9.5 hours per day Monday to Friday. Early in the Spring 2009, neither the IC nor the Student Health Center had an accurate estimate of the number of infected individuals. All available estimates on the actual number of patients had significant margins of error.

The IC's actions focused on maximizing the available capacity at the healthcare center by changing the working schedule of doctors and nurses. Additionally, arrangements were made to have on-call access to additional medical support from one of the community hospitals in the area. However, such arrangements did not consider that hospitals themselves could have faced an increasing demand of services during the pandemic, and that such demand could have varied for pandemics with different mortality and morbidity.

Overall during the H1N1 pandemic the center was able to cope with the number of influenza cases during the season without the need of hiring new personnel.

6. Class disruption:

One of the main concerns that the university community had with regards to the H1N1 pandemic was how it would disrupt classes and day-to-day campus activities. For students and parents it was important that the school year would not be delayed. Any postponement in the graduation day of a student was likely to result in additional costs for the student and the university. For the university, long class interruptions had a negative effect on the number of prospective students, who might have chosen to apply to other universities with undisrupted schedules.

The committee's work focused on setting up guidelines to help students and faculty deal with likely absences. Faculty was required to design their syllabi in such a way that they could provide a flexible grading scheme and remote access to course material. Although faculty were receptive to the idea of avoiding course interruptions, there were concerns about how students would perceive an online course, and whether evaluations for these courses would be considered differently for academic promotion.

7. Food logistics during the pandemic:

The IC addressed the need to ensure meals to students affected with H1N1 if they were isolated in their rooms. Campus food services were asked to have a 2-week inventory of supplies to provide boxed meals to the students at their residences during the peak of the pandemic. Ill students needed to report to the healthcare center in order to receive meals delivered to their rooms.

8. Class suspension:

The committee knew that public healthcare authorities could have provided recommendations on whether classes were to be suspended and if isolation needed to be enforced. However, the IC agreed that such decisions could be taken too late, and that if the disease severity was high, the university would have missed the window of opportunity to effectively protect its students, faculty, and staff. Consequently, the IC unanimously recommended that the university pro-actively took action and did not wait for public health authorities to recommend a school closure. However, the IC was unable to suggest what factors and under which conditions such decision should have been adopted. Suspending classes had many consequences, including for example, the financial cost of paying faculty and staff during such a period, and the cost associated with overtime required to recover any missed teaching time. Additionally, since any suspension of classes would most likely occur during the Fall or early in the Winter, the school year would have had to be extended over the summer, which for students meant missing internships and full time job opportunities. Furthermore, many students would have needed to enroll in an extra term to take courses that were not offered in every academic period.

C. Key lessons from H1N1 2009-2010

Several lessons are likely to influence future planning efforts:

- If a new influenza virus appears, for at least 6 months there will not be an available vaccine.
- Vaccine distribution could begin as early as 6 months or as late as 9 months after the flu virus is first characterized.
- The lethality and infectiousness of the virus will directly affect any plan for containing the disease.
- Any RIT response plan to a new pandemic will have to consider the implementation of actions before and after vaccines become available to students, faculty, and staff.
- It is important to establish social distancing strategies to minimize the rate of infection among students and faculty.
- Independent of the influenza characteristics, the most problematic time for having a pandemic will be the Fall, because the university will have to deal with the consequences of the disease during the entire academic year.

D. Revisiting RIT's Pandemic Response Plan

It is the first day after Labor Day and RIT’s Provost, has just finished his morning exercise routine. He is now getting ready to join the President at the inauguration ceremony of the new academic year. This time of the year usually brings the opportunity to revise institutional plans and set up new strategies. For this year, one of the key plans that the Provost aims to revisit is the Pandemic Response Plan that was adopted after the 2009 H1N1 pandemic. Although great things happened during the 2009-2010 academic year (e.g., the men’s hockey team made it to the NCAA finals) he cannot forget the uncertainty and concern he felt at 2009's academic year inauguration. At the time three questions preoccupied RIT administrators: *How many of our students will be infected with H1N1? Would there be any fatalities? What should RIT do to deal with the pandemic?*

Although, during the Summer of 2009, public health officials had warned that the H1N1 epidemics was not as lethal as expected, as Labor day approached, parents started calling the Provost's office to inquire about the university plans for mitigating the spread of the H1N1 virus in campus, and about how their children were going to be protected. Parents asked whether the university would vaccinate students and if the school year would be delayed. They also asked for details on RIT actions if their children became infected in campus. Due to the number of calls, the Provost frequently repeated his speech: *We are doing everything we can according to the recommendations of the national and state public health officials. We have made all necessary arrangements to avoid any teaching disruption and we will make sure that student's health and safety is RIT's number one priority*. However, no matter how many times he repeated those words, he was always concerned, and often wondered if there was anything else that could be done.

Although 2009 pandemic is now part of history, RIT's Provost is aware that a more lethal type of influenza can occur at any time and for that reason he wants RIT to revisit its response plans. Although, the RIT community reacted well to the H1N1 pandemic, if H1N1 had been a bit more lethal, the strategy adopted by the university may not have been effective. The Provost would like to review the preparedness plan for future pandemics, and would like the assessments to be analytically based and to provide clear guidance on how to manage the school resources during different and potentially more severe outbreaks. He wants RIT to have the capacity to react to any flu pandemic.

PART 1: Can we make sense of a disease as it spreads?

Consider the information provided in Table 1, which contains the daily number of students diagnosed with influenza-like illness (ILI) at RIT during the H1N1 pandemic in 2009-2010.

1. Plot the number of students with ILI over time. Can you explain why the number of patients with ILI shows the distribution depicted in your graph?
2. Can you identify a model to explain the number of newly infected individuals at RIT over the course of the H1N1 pandemic? Describe the strengths and the limitations of your model. You may want to consider the following in your analysis:
    - What role can forecasting the number of new patients with ILI have on RIT's decision-making if a new pandemic occurs?
    - How often would you forecast the number of students with ILI and why?
    - What would you use as the causal variables for your model? Explain why.
    - What challenges do you foresee in collecting the necessary data?
    - Do different infectious rates have an effect on the forecast accuracy?
3. How accurate is your forecast?
4. Could your model have been useful during the 2009 H1N1 pandemic? Can it be useful for responding for future pandemics? Explain why? Or why not?
5. Correlate the information provided on the number of patients with ILI at RIT (Table 1) with the percentage of visits for ILI Reported by the U.S. Outpatient Illness Surveillance Network (ILINET) (See: http://www.cdc.gov/flu/weekly). Comment on the results of your analysis.

Part 2: Suspend or not Suspend? That is the question!

You have been asked to be part of the team of experts who will help RIT review its preparedness plans for future pandemics. The challenge that RIT faces in preparing these plans are primarily the uncertainty regarding the lethality and severity of the influenza strains, as well as the time needed for having an available vaccine. As requested by the Provost, RIT preparedness plans need to be analytically based, and provide clear recommendations on what RIT should do if a new pandemic occurs.

The key concerns that you have been asked to consider in the preparedness plans are:

1. Under which conditions should RIT suspend classes?
2. How many beds and how much space should RIT set aside, if patient isolation is recommended for those with ILI (influenza like symptoms)?
3. What is the number of doctors and nurses on staff needed at the university's health care center during a pandemic?
4. What level of antivirals should RIT stockpile (if allowed)?
5. What level of masks and gloves should RIT stockpile?

Consider using an epidemiological compartmental model to simulate the progression of different pandemics at RIT. Compartmental models have been commonly used to understand the spread of infectious diseases in a population. For an example of a compartmentalized model consider SEIR (Susceptible-Exposed-Infectious-Recovered model), which assumes that a patient can transition through the following health states (compartments) as a consequence of influenza: *susceptible*, *exposed*, *infectious*, *recovered*, and *dead*. For more details on these models refer to [11-14]. SEIR assumes that a *susceptible* individual can be *exposed* to an influenza virus and remain in a state of latency (non-symptomatic stage) for several days before the patient becomes *infectious* and symptomatic. Additionally, after several days an infectious individual can *recover* from the disease and become immune to it, or due to further complications the patient can die. It is assumed that the population growth during the duration of a flu epidemic is negligible, as well as the death rate from other diseases. You may want to modify the SEIR model for your analysis.

For your compartmentalized model consider that the following information is known (these are parameters):

- The probability that a contact between an infectious and a susceptible individual results in the susceptible individual becoming exposed, β
- The probability that an exposed individual becomes infectious, a
- The probability that an infectious individual recovers (i.e., the reciprocal of the infectious period), ν
- The probability that an infectious individual dies due to the infection, d
- The probability that a vaccinated individual acquires life-long immunity to the disease, P
- The probability that a susceptible individual is vaccinated, r
- The number of days after the first infectious individual appears in campus for vaccines to be available, k.

Implement your compartmentalized model in Excel and then propose an experimental procedure that will allow you to observe the evolution of different flu pandemics scenarios at RIT. In this experimental design, you will define testing scenarios by setting different parameter values for the data required by your model to run. You should consider different *severity levels* (% of infected individuals who die), different *infectiousness* (i.e., the number of individuals that get infected by one infectious patient), and different *availability of antivirals and vaccines*.

Remember that the model is not the final delivery of your work, it is a tool that will help you develop a preparedness plan for future pandemics that addresses the 5 concerns listed in the previous page. Your plan must be quantitatively based and easy to use for non-technical administrators.

A challenge you will face is the lack of information on the triage procedures and the way the medical center will interact with infected students. Such procedures will depend on the severity of the pandemic virus. However, consider the interaction you have experienced when visiting a provider in order to estimate the amount of time a nurse and a doctor spend on each patient.

Complementary Readings:

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Appendix

Table 1: Evolution of patients with Influenza-like symptoms at RIT during the fall of 2009 and Spring of 2010**.** F11 and W11 correspond to the exam weeks of the Fall and Winter quarters, respectively. RIT was closed during W8 and W9 due to Christmas break.

Quarter and Week F: Fall, W: Winter S: Spring	**Number of patients with ILI**
F 0	1
F 1	7
F 2	6
F 3	4
F 4	3
F 6	6
F 7	11
F 8	59
F 9	114
F 10	130
F 11	34
W 1	9
W 2	6
W 3	2
W 4	5
W 5	4
W 7	2
W 10	2
W 11	1
S 4	1

Optimization Case Study: (25% of your course grade)

The Residence Scheduling Problem at RGH

Medical residency is a stage of graduate training for medical professionals required for their practice of medicine. Individuals who have attained a medical degree (M.D., D.O., or MBBS, MBChB, or Bmed) need to practice medicine in a hospital system offering a residence program under the supervision of senior physicians. The duration of residence programs is typically of 3 years but it may defer for rotations on specialized fields such as neurosurgery.

Rochester General Hospital (RGH) is a 528-bed tertiary-care facility in Rochester NY, served by more than 1,500 medical and dental staff members and more than 7,000 employees.

In 2012, the volume of service provided by RGH was reflected by the following numbers:

Inpatient Discharges	31,644
ED Total Visits	101,616
OP OR Procedures	18,880
Observation Visits	10,314
RGMG Encounters	378,548
Clinics	114,497

The resident program at RGH is a 3-year rotational program in Internal Medicine that receives nearly 20 new residents every year and maintains an average of 60 residents in total. The rotational calendar year starts every June and extends over a 12 month period. Every Spring, once new residents are admitted to the program, a group of chief residents work for two months determining the rotational calendar for the following academic year. The new rotational calendar must be ready and approved by the end of May. The process of scheduling residents is typically performed without the assistance of a decision support tool. The chief residency position at RGH is a one-year rotational position offered to a small and selected number of residents once they have completed their 3-year rotation.

Scheduling resident rotations is not a trivial task. Internal policies, managerial practices, as well as regulations affect how hospitals can schedule their rotations, resulting in labor intensive and expensive scheduling process. Determining the rotational schedule can be considered a two-stage problem. In "stage 1", the goal is to generate a schedule that indicates in which unit residents should rotate during every single week. In "stage 2", the output of stage 1 is used as an input to determine the days of the week and the daily shifts that residents should follow to comply with the weekly schedule.

For the residency program in RGH it is extremely important to have a high quality rotational schedule. Such a schedule will not only help to provide medical care in different hospital units, but its quality is key to attract new residents interested in doing their rotations at the hospital. A good schedule, should allow residents to explore and experience a large number of hospital units, have a balanced professional life, and be easy to implement.

Residents can rotate through several rotational units grouped in three sets: Elective, Inpatients, and Ambulatory units, which are described by:

- Electives (1): incorporates a myriad of small units all of them referred as "Electives".
- Ambulatory (3): Geriatrics, TWIG, and OPD.
- Inpatient (13): R1F, HemeF, CardF, FloatF, TCB1, TCB2, MICU_D, MICU_N, MAT_D,

MAT_N, RNAT, Midcall, Overnight.

Each resident is assigned a permanent post in an outpatient clinic (TWIG, or OPD) where they must work during their 3-year program. After 4 weeks in which residents rotate in different units, they have to be back at their assigned outpatient clinic to do a one week rotation. Additionally, to ensure continuity of care in the outpatient clinics, year 1, 2, and 3 residents are assigned to 5 clinic groups. Residents in the same clinic group have the same outpatient clinic as their permanent posting. The hospital must ensure that at least one member of each clinic group is rotating at their clinic every week.

In developing the “stage 1” schedule chief residents must ensure that:

- each resident has two two-week non-consecutive vacation periods per year.
- residents do not undergo more than 3 consecutive night shifts (i.e., in units Overnight, MICU_N, MAT_N).
- for each resident, a third of all the rotational time must be spend in Elective units, a third in Ambulatory units, and a third in Inpatient units.
- a resident cannot be absent from his/her appointed clinic (either TWIG or OPD) more than 4 weeks.
- not all units require rotations, while some require rotations every week
- for each rotation, a unit must be assigned with the right number of year 1, year 2, and year 3 residents. There is a minimum and maximum number of residents of each year required for the rotation to happen. A number of residents within these limits can be interpreted as a team. Some units allow multiple teams to rotate at the same time, whereas the following units allow up to one team in rotation in any given week: R1F, HemeF, CardF, FloatF, TBC1, TBC2, MAT_D, MAT_N, Overnight, Midcall, MICU_D, MICU_N. Other units can accommodate more than one group of residents in rotation.
- each rotation is scheduled to last a number of consecutive weeks between a minimum and a maximum number defined by the unit.

During any week, residents who are not assigned to a rotational unit, to their outpatient clinic, or are not in vacation must be assigned to a “Sick Call ” rotation. If a resident is in “Sick Call”, she or he is allowed to rotate in any elective unit and during this time the resident is on-call (or stand-by) and would be asked to replace other residents who may be absent from their rotational post due to unplanned reasons.

Given the data used by chief residents, it is very likely that there is no schedule that can simultaneously (and optimally) accommodate all the aforementioned restrictions. Therefore, the goal of the chief residents is to develop a “stage 1” plan that tries to accommodate the resident choices and vacation preferences, all scheduling restrictions, offers residents the opportunity to have a high number of elective rotations, and is fair among the residents.

Residents express their vacation preferences by assigning a number between 0 and 10 to weeks when they would like to have vacation. A higher number reflects a higher preference. For example, a resident would assign a preference value of 10 to the four weeks when she is most interested in having vacations, and perhaps 7, and 6 to other two-week blocks that are less desirable. Not all weeks of the year are given a vacation preference, in which case their value is assumed to be zero (no preference). Residents can also express their dissatisfaction for having vacation in certain weeks of the year, by assigning negative numbers between -1 and -10 . The most negative the preference, the most dissatisfied the resident would be if a vacation is assigned in such a week.

A “fair schedule” for RGH is a schedule where the number of weeks in rotation in difficult units is balanced among the residents. In particular the total number of weeks in night shift rotations (i.e., Overnight, MAT_N, and MICU_N) is as similar as possible among the residents. This will prevent situations in which some residents have too many overnight rotations and others too few.

Finally, you must consider that in implementing your schedule you should be able to take into account the rotations that year 2 and year 3 residents have already performed.

DATA FOR THIS PROJECT

Data available for developing stage 1 schedule is given below:

Year 1 resident (R1) IDs: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Year 2 resident (R2) IDs: 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38

Year 3 resident (R3) IDs: 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57

Table 1: Resident types allowed for a rotation in each unit :

Unit	R1	R2	R3
Geriatrics		Yes	
R1F	Yes		Yes
HemeF	Yes	Yes	
CardF	Yes		Yes
FloatF	Yes	Yes	
TBC1	Yes	Yes	
TBC2	Yes		Yes
MAT_D		Yes	Yes
MAT_N		Yes	Yes
Electives	Yes	Yes	Yes
VAC	Yes	Yes	Yes
RNAT	Yes		Yes
Overnight	Yes	Yes	
Midcall		Yes	
Sick Call	Yes	Yes	Yes
TWIG	Yes	Yes	Yes
OPD	Yes	Yes	Yes
MICU_D	Yes	Yes	Yes
MICU_N	Yes	Yes	Yes

Table 2 describes the minimum and maximum of consecutive weeks of a rotation in a unit, if scheduled. Columns three and four describe the minimum and maximum number of weeks of rotation a resident could complete in each unit during a year. These two columns of information together with Table 4 indicate whether residents must be in rotation in a unit every year or some of the three years in the rotational program. Having no annual minimum required implies that rotation in the unit is not mandatory. In Table 2, having no annual maximum indicates that there are no restrictions in the number of rotational weeks.

Table 2:

Unit	Minimum duration of each rotation (in weeks)	Maximum duration of a (in weeks)	Minimum number of weeks of rotation a resident must complete in a year	Maximum number of weeks of rotation a resident must complete
Geriatrics	2	2	4	4
R1F	2	4	2	4
HemeF	2	4	2	4
CardF	2	4	2	4
FloatF	2	4	2	4
TBC1	2	4	2	4
TBC2	2	4	2	4
MAT_D	2	2	2	
MAT_N	2	2	2	
Electives	2	4		
VAC	2	2	4	4
RNAT	2	4	4	4
Overnight	2	2	4	4
Midcall	2	2	4	4
Sick Call	1	2		
TWIG	1	1	10	11
OPD	1	1	10	11
MICU_D	2	2	2	8
MICU_N	2	2	2	8

If a rotation for a unit is scheduled then the number of R1, R2, and R3 residents in the rotation must fall between the ranges suggested in Table 3. Remember that not all units are required to have a rotation every week.

Table 3: Minimum and maximum number of residents needed to schedule a rotation in each unit

	R1		R2		R3	
Unit	Min	Max	Min	Max	Min	Max

Geriatrics	0	0	1	2	0	0
R1F	1	2	0	0	1	1
HemeF	1	1	1	1	0	0
CardF	1	1	0	0	1	1
FloatF	1	1	1	1	0	0
TBC1	1	1	1	1	0	0
TBC2	1	1	0	0	1	1
MAT_D	0	0	1	1	1	1
MAT_N	0	0	1	1	1	1
Electives	0	19	0	19	0	19
VAC	0	2	0	5	0	5
RNAT	0	2	0	0	1	1
Overnight	1	2	1	1	0	0
Midcall	0	0	1	1	0	0
Sick Call	0	unlimited	0	unlimited	0	unlimited
TWIG	1	2	1	2	1	2
OPD	1	3	1	2	1	2
MICU_D	2	2	1	1	1	1
MICU_N	1	1	1	1	1	1

Table 4: Minimum and maximum number of weeks of rotation residents must complete over a 3 year period.

Unit	Min	Max
Geriatrics	4	4
R1F	6	12
HemeF	6	12
CardF	6	12
FloatF	6	12
TBC1	6	12
TBC2	6	12
MAT_D	4	unlimited
MAT_N	4	unlimited
Electives	0	unlimited
VAC	12	12
RNAT	0	unlimited

Overnight	0	unlimited
Midcall	0	unlimited
Sick Call	0	unlimited
TWIG	30	33
OPD	30	33
MICU_D	12	24
MICU_N	12	24

Information regarding the vacation preferences of each of the residents as well as the number of weeks of ration already performed by R2s and R3s is available in spreadsheets provided in myCourses. Additionally, an older schedule has been provided in myCourses to illustrate the output format in which your model should provide its outputs

For Stage 1:

- Develop a mathematical programming formulation for the scheduling problem that reflects the interests and goals of the resident rotational program at RGH.
  - What is the best way to measure the effectiveness of your schedules?
- Implement your formulation in AMPL using any solver of your choice.
- Your implementation should be designed to automatically output a schedule to MS Excel in a format similar to the example schedule provided in myCourses.
- Additional points will be given if the parameters to your model are read directly from Spreadsheets or from a database

Deliverables:

- A 20 minute slide presentation describing your methodology, assumptions, your solution, and your performance.
- An 10 page report (maximum) that describes your model, implementation, and your analysis. You can have up to 2 pages of appendices. Font 11, Times New Roman, on-and-half line spacing.
- Your report will be graded based on its content, clarity, and conciseness.

Evaluation Rubric:

  - Project 100 points = 25% of final grade
    - Presentation 30 points
      - Time management/ Clarity – 10 points
      - Ability to convey technical work to a non-technical audience – 10 points
      - Ability to answer questions about your work – 10 points

- ▪ Report 30 points
  - Quality of your model - 10 points
  - Clarity and easy of reading - 10 points
  - Conciseness and structure of the report - 10 points
- ▪ Quality of your schedule – 40 points
  - To assess the quality of your schedule, you will generate an excel schedule in the same format provided to you as an example. This schedule will be assessed by:
    - How feasible it is -10 points
    - How well it satisfies vacation preferences – 10 points
    - The number of elective rotations that residents have – 10 points
    - How fair it is – 10 points

<u>Bonus points:</u>

Additional 10 points will be granted to the group based on how well the schedules compare to those of other groups (comparing the schedule quality on the 4 mentioned metrics) All schedules will be ranked using AHP. The top 3 schedules will receive 10 additional points, and the next 3 schedules will receive 5 additional points. The bottom two groups will not receive any bonus points.

<u>Due dates:</u>

- **Oral Presentations – December 9-10 (Schedule to be coordinated with each group)**
- **Final Report – December 11 @ midnight**

Complex Problem Solving and Decision Modeling in Economics

ESCB—705; Economics & Decision Modeling taught by Professor Steven Gold. Professor Gold created an interactive simulation game which requires students to work in varying market conditions (monopoly, oligopoly etc.) and to manufacture and sell products while competing with each other. The game drives a hands-on understanding of a complex array of economic factors that impact an industry, and provides for team and individual decision making. ACT – applied, requires assessment, critical review of complex data, requires decisions based on your thinking.

Complex Problems and Uncertainty in Business Consulting

MGMT—550; MGMT—753 (same class has both grad and under grad students working together); Field Experience in Business Consulting. This course by design – places students into teams, assigns them a real world business problem to solve with the associated client company or organization. Throughout the course students must wrestle with ambiguity, uncertainty while they design and execute on primary and secondary research, collect and analyze data in order to address the objectives of their business project. Students use the academic disciplines they have learned in their other classes to address real world business problems on behalf of a client. They need to be critical reviewers of the data they collect in order to draw sound conclusions and to make the best recommendations to their client.

Technology of the Day Assignment
Sarah Brownell

Although the media often portrays them as such, no technological solution is a panacea; no one product or system can solve the problems of poverty for every user. Being able to get beyond the hype and critically evaluate technologies and systems for your application is critical to doing good development work. However, even if a technology fails in the original application, there is often a niche in which a design can be beneficial and even have large impact—with a few modifications to the original design, new methods of dissemination, or a new understanding of who your product's user is. Think of One Laptop per Child and how it drove innovation for cheaper laptops for US market, reaching more people at lower income levels. Think of the Comet light treatment device by DRev which didn't serve well in rural clinics, but has increased treatment for jaundice at larger hospitals, saving the lives of many babies. Design for development is an evolving process.

Your assignment is to select a promising technology/method/system design for the developing world and complete two assignments: a "Tech of the Day" case study presentation and a final Triple Bottom Line analysis. The triple bottom line assignment is described in a separate document.

In teams of two, students will choose a different technology and sign up for a presentation date throughout the semester. You may choose from one of the technologies/systems/methods below or find your own. However, if you choose your own, you need to make sure that there is enough information available on your topic to do an adequate study (check with your instructor).

- Play pump (water supply)
- SODIS solar disinfection (water treatment)
- Community Led Total Sanitation (CLTS) (sanitation)
- Biofuel from jathropa oil (energy/transportation)
- Treadle pump (water supply/agriculture)
- Improved cookstoves (energy/health): Rocket, Lorena, Jiko stoves, thermo-electric stoves, etc (pick one as a focus)
- Biochar (agriculture/energy): Making charcoal briquettes from agricultural or office waste, soil amendments, carbon sequestration, building materials (pick a specific technology or method)
- Drip irrigation (agriculture)
- Gravity Light (energy)
- Microfinance (see Poor Economics for good info) (jobs)
- Peepoo bag (sanitation)
- Lifestraw (water treatment)
- Potters for Peace water filters (water treatment)
- Madidrop or Drinkable Book (water treatment)
- Infant formula in developing countries (health)
- Cell phone applications (you must choose a specific one) (communication/education)
- Indigo Solar (energy)
- Solar cookers (pick a specific type for your analysis: panel, box, parabolic) (energy)

- Bogo lights (energy)
- Non-pneumatic anti-shock garment (maternal health)
- Ready to Eat Therapeutic Food (health/nutrition)
- sOccket ball (energy)
- Maya pedal technologies (energy)
- Jaiper foot (health)
- Avarind eye care (health)
- Samasource (jobs)
- CAWST slow sand filter

Tech of the Day Presentation:

You will present your "technology" in the context of the global problem it seeks to address and show its advantages and disadvantages compared to other technologies that attack a similar problem. Your goal is to critically evaluate the technology ***(you are not trying to sell this product to us!),*** find the appropriate niche for your technology, identify risks and criticism, and then suggest some ways that the design might evolve to reach more people or have more positive impact.

Please include the following topics in your presentation (use whatever order makes sense for you). Try to be clear, concise and convincing! Your presentation should be no more than 15 minutes long. **Practice!**

1. Problem (1 point): The world problem(s) that the technology addresses. What is the extent of the problem? What is the impact of the problem—how does it affect people? Give the hard evidence (data) as to why something needs to change… Why should we care about the problem or the people affected? Make us care. Break our hearts.
2. 5 whys (2 points): What are the underlying issues causing this problem? Try using the 5 why's technique. Do a little research to guide your intuition—check to see if your intuitive responses seem to be true (backed up by data). You can have more than one branch to the "why" chart. What "why" does your technology address? Do you think this is the main "why" that should be tackled in solving the problem or might there be other more important "whys"? See examples:
    a. http://eliminatethemuda.com/2010/02/why-cant-i-save-money/
    b. http://www.bulsuk.com/2009/07/5-why-analysis-using-table.html#axzz1ovgzrGaa
3. History of the technology/solution (1 point): A description of the technology itself, where the idea came from, and the motivation behind its development. At what level does it address the underlying causes of the problem, if at all? Is this the "best" place to attack the problem (in your opinion)? Have there been any scientific studies of the technology or its effect in the real world? Show any data that you find. How robust were the studies?
4. Other Technologies (1 point): A brief examination of other technologies used to solve the same or similar problem. **Be sure to include work-arounds and solutions used currently by the poor** (such as getting water from the river or using open fires to cook) even if they are not ideal solutions. **Look back in time** to see how the problem was addressed in the past and what

motivated the search for better solutions. Also include solutions used by the wealthy or people in a developed country.

5. SWOT analysis: (2 points)
    a. Strengths of the product or system itself (unique benefits compared with other solutions)
    b. Weaknesses of the product or system itself (unfulfilled user needs, areas where it may fail the user, harms it may cause)
    c. Opportunities for the product or system in the world (factors **external** to the product that might cause it to take off in sales/use and have impact, also opportunity areas to increase the products value for users)
    d. Threats for the product or system in the world (factors **external** to the product that might hinder its sales/use and therefore impact on the problem)
    e. For SWOT examples see:
        i. http://gliffy.pbworks.com/w/page/41567057/SWOT%20Analysis%20Example
        ii. http://www.scribd.com/doc/2673526/SWOT-Analysis-Examples
        iii. The O and T sections should be things that are happening whether or not this product exists. For example, changes in law, regulation, or policy, new trade opportunities, new funding sources, societal trends, new research results or new technology, climate change, demographics, etc.

6. Ethics and Risk: Are there ethical questions related to the product/system or how it is distributed? Is there a controversy over this idea? What could go wrong? How might the technology be misused? Is it fair? Who wins and loses? What values are imbedded in the idea? From your ethical perspective, what are the risks to users or the company or the environment?
7. Conclusions and recommendations (1 point): Summarize your main findings and then make recommendations for how this technology might be applied or adapted for the most positive impact.
8. Honest Evaluation (1 point): Have you assessed this technology honestly and fairly?
9. References (1 point):
    a. Each team must have at least two peer reviewed journal articles referenced. These articles might relate to the problem, the theory behind your product/system, or to the product/system itself.
    b. All facts, data, quotes, tables, and pictures (unless they are your own pictures) used in your slides must be credited or referenced—include links if applicable. Facts should be referenced to their original source (published paper, World Health Organization, UN or government bodies, etc.), **rather than some popular article or non-profit organization's website**. In order to reduce distraction in the presentation, references can be included in a small textbox near the picture, at the bottom of the slide, or numbered end-notes in a separate slide at the end.
10. Time management: 10% penalty for being over time by more than 2 minutes.

Critical Analysis Assignment for Scholarly Articles

This is an exercise I use in my Design for the Environment class that really helps students think deeply about a reading.

The class is broken into a number of teams, let's say 8. During a specific week one team will be assigned the task of reading and defending a specific research paper (Team A). The goal is for Team A to present the paper to the class as if they were delivering it at a conference. Another team (Team B) will be assigned the task of reading the paper and challenging the work. After Team A presents, Team B interrogates them challenging the paper's perceived weak points. This forces Team B to think hard about the paper's strengths and weaknesses, and it forces Team A to do likewise in order to anticipate the questions that they are likely to get from the challengers.

I find that this exercise really motivates the students, especially grad students who are involved in their own research work. Each team will have 3 or 4 opportunities to defend a paper, and each team will have 3 or 4 opportunities to challenge a paper. I also benefit, because I get to hear presentations on interesting research topics along with a critical assessment of the study's strong and weak points.