Building Redevelopment for Repurpose

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Abstract:

Recently, students have expressed displeasure in the current availability of study spaces in and around the campus. Meeting this need for more private group conference areas is tough to achieve without making significant changes to the current flow of campus. WPI's Stratton Hall and Project Center have been focal points of WPI's campus since the early 1900s; however, they are currently outdated. A renovation that addresses the need for more spaces will be endearing for all WPI students and faculty. This project is a design proposal for a renovation and a building connection between Stratton Hall and the Project Center that will also resolve accessibility issues with the two buildings through the incorporation of an elevator.

Acknowledgements:

Leonard Albano: We are extremely grateful for the guidance Professor Albano provided us throughout our project. From helpful discussions on determining on project, to providing names of individuals that could help, to reviewing and commenting on our work, Professor Albano helped guide us and maintain on track throughout the whole project.

Eric Beattie: We like to personally thank Eric Beattie**,** VP of Campus Planning Facilities, for helping us discover our project and ways to try to improve campus for following classes through our work. Mr. Beattie provided us information regarding current conditions with Stratton Hall and the Project Center specifically.

Amy Smid: We like to thank WPI Archives more specifically Amy Smid for helping us determine the existing conditions of Stratton Hall and the Project Center by providing all previous construction documents of the buildings that were available.

Aaron Sakulich: We like to thank Professor Sakulich for providing information and surveying equipment in order to determine the current floor elevations within each building that was reviewed.

Professional Licensure Statement:

Professional Licensure is a certification that distinguishes certain individuals as qualified to work in their chosen profession. In architecture and engineering, it is important for practitioners to obtain professional licenses to minimize safety risks to the general public and to ensure that unqualified people are not doing jobs for which they are not qualified. Professional licensure enables the people that obtain them to seal and sign off on specific architectural, engineering, and construction documents. In addition, licensure enables individuals to obtain higher positions with room for continued growth in the field. Licenses are obtained in the United States from the jurisdiction where work is being done (i.e. one of the 50 states or territories). In the construction industry there are many types of Professional Licensure. Depending on whether one is becoming an Architect, a Civil/Field Engineer, or a Construction Manager/Superintendent, each has their own respective licenses.

In order to practice architecture, it is necessary to obtain a license from the state where the practice is being done. Each jurisdiction has different requirements; however, they all follow a similar general format. The first step to obtaining a professional license in architecture is to obtain an architecture degree in a NAAB-accredited program. Next, each applicant is required to gain professional experience under a professional architect and document it; all jurisdictions accept the *Architectural Experience Program* (AXP). Once completed, each applicant must successfully pass the ARE or the *Architect Registration Exam.* The final step would be completing any jurisdiction-specific requirement and then the *National Council of Architectural Registration Board* (NCARB) will need to be transmitted, recorded, and updated when needed.

The process to become a professional engineer is very similar to that of an architect. First, all applicants must complete a four-year degree program at an ABET-accredited engineering school. Once out of school, the applicant must complete the *Fundamentals of Engineering Exam (FE exam)*; this exam covers all topics discussed in general engineering classes unspecific to the focus of study. There are also popular versions of the FE exam that are discipline specific. Four years of progressive work must then be completed under a licensed and practicing professional engineer. Finally, after four years of practice, the applicant must complete the *Principles and Practice of Engineering Exam (PE exam)*. It is then when they can apply for a license in their respective jurisdiction and complete any additional requirements.

To become an occupational licensed supervisor for a construction manager or superintendent role, the state of Massachusetts requires a minimum of three years of field experience prior to registering for the *Construction Supervisor License test*. If the *Construction Supervisor License test* is passed, results will need to be sent and recorded by the Board of Building Regulations and Standards, this is also where renewals of licenses will occur.

Capstone Design Statement:

This project incorporates designing an addition connecting Stratton Hall and the Project Center on Worcester Polytechnic Institute's (WPI) campus. The team must design a space that evaluates the current flow of students through campus, addresses the need for more study spaces, considers and improves accessibility for both Stratton Hall and the Project Center, and develops a structurally sound addition, while planning and limiting the effect of any new construction on the campus and the surrounding neighborhood. To best provide WPI with a comprehensive design proposal and to fulfill the WPI capstone criteria for Accrediting Engineering Programs by the Accreditation Board for Engineering and Technology (ABET), the following six realistic constraints were considered:

Environmental:

Construction of all forms disrupts the natural flow of the environment surrounding it- from the destruction of existing habitats to the addition of added emissions from construction equipment and production of carbon dioxide. The City of Worcester, in coordination with current building codes as well as its new sustainability plan, ensured that wildlife as well as the neighboring community was not directly impacted with, for example, worsening air quality and degradation to land. The team developed multiple design alternatives that encompassed an initial environmental analysis of all construction that took place. This analysis was then considered in choosing the final design. Another constraint that directly impacted the nearby community was noise pollution. Construction created a lot of noise that indirectly impacted the neighboring community. It was important to control the above constraints to our best ability throughout the project in order to keep in good standing with the community. This was done through the use of surveys and prior experiences. An example of a solution we came to is construction scheduling and attempting to keep as much of the heavy work in the summer months as we can.

Health and Safety:

With demolition and renovation to older buildings there were health and safety constraints that were considered. The first constraint was dealing with hazardous building materials. It was imperative to find and determine hazardous building materials that were up to previous codes- such as asbestos and lead paints. Next, while working in a pandemic, it was important to consider possible delays due to any unexpected outbreaks. Finally, structural safety and fire safety needed to be considered as well. The team worked in alignment with current building codes, the City of Worcester, and WPI facilities, as well as current ASTM standards, to ensure all safety guidelines were followed. Zoning ordinances were considered to ensure our use for the space was coherent with the specified uses (i.e. no residential housing was designated for the space).

Constructability:

Given the current market of construction materials, it was difficult to determine whether currently scarce resources, such as steel and lumber, would be available during construction. Furthermore, another constraint related to constructability was the location of the project. Although the project site is zoned for Institutional use, it was imperative to continue to consult and follow the zoning ordinances for corresponding constraints and guidelines. Likewise, the location of the project made it more difficult to continue to construct and build due to its close proximity to other buildings, as well as being up on a hill. The Project Center and Stratton Hall also have different and dated exterior facades and building materials, so blending the two buildings together included both engineering and aesthetic challenges. The team balanced these constraints with most importantly making sure they were all structurally sound in creating a final proposal.

Sustainability:

When renovating any building and conducting selective demolition, sustainability is often a common concern; new buildings are often more efficient and provide less waste. The City of

Worcester had recently established a new plan called *Green Worcester Sustainability and Resilience Plan.* The plan outlined that by 2045 each building needed to use 100 percent renewable energy and limit emissions to an almost complete net zero. In proposing a design, the team directly adhered to the general sustainability plans set by the City of Worcester, as well as those set by WPI. The proposed design included a curtain wall in order to help promote passive solar to better control climate in a cost-effective and climate-friendly method.

Social:

With any construction project there are multiple social externalities that need to be taken into consideration. The first social constraint that was considered was where students and faculty were displaced to because of the construction. The construction was predicted to take longer than a WPI summer of work, so it was necessary to determine other means of temporary offices and spaces for faculty and students that were affected. Furthermore, Stratton and the Project Center sit close to where West Street once crossed the WPI campus. This path is high traffic for students walking through campus and was affected by the construction due to the space necessary for machinery and material storage. Finally, the project had to be socially accepted, as WPI had push back on the Innovation Studio which was meant for students. Through the use of surveys, the team attempted to address the concerns of current students and faculty, while still proposing a design solution and schedule which limited the amount of people displaced.

Economic:

Another constraint that the project took into consideration was any economic issues that the project encountered. First, the school had a set budget as far as how much could be spent, and it was important to consider this when designing the project, especially since it was most likely being privately funded. Next, it was important to realize that with the scarcity of resource materials such as lumber and steel (as discussed in previous sections) that prices were elevated and could change drastically, which could affect the economic constraints set by the Institution. The project team took into consideration this constraint as we evaluated the costs of the design and then used the analysis in making a decision for the final proposal.

Authorship:

Madison Di Vico: Madison Di Vico's main responsibilities included research on precedent studies that provide inspiration for the wants and needs of the building. From there Madison created building programs for each level that were further developed into floor layouts. Using her industry experience, she researched and added necessary fire protection systems to the building and performed an egress analysis. Madison also created the final 3D model for the building expanding the Revit model of the existing conditions to include the construction of the new building. Finally, Madison worked in collaboration with her team to review all submitted work and write/edit the MQP report.

Dan DiVecchia: Dan DiVecchia's core responsibilities included preliminary research and writing about the construction and design consultation process, building history, and construction software. Dan also created, distributed, and analyzed multiple surveys regarding students' desires for a new academic space on campus. On top of aiding in pre-design for the proposed project, Dan used field data collected to create a Revit model of the existing conditions which was later incorporated into the final deliverable. Moreover, Dan used industry experience as well as knowledge gathered from previous classes to develop a comprehensive cost estimate, analyze zoning bylaws, and provided context for the proposed designs. Finally, Dan helped to evaluate all submittals, design decisions, and writing/editing for the MQP report.

Ethan Schock: Ethan Schock's principal responsibilities were assessing and measuring existing conditions by the collection of field data, developing the construction timeline, assisting in the design of the interior spaces, and taking a lead in team communications. Furthermore, Ethan also contributed to researching, writing, and revising the term submission and the MQP report.

Justin Hines: Justin Hines's responsibilities throughout the project included the structural analysis of the building. This included sizing the structural beams, columns, and girders as well assessing the member connections. Additionally, Justin collected data from the site to be used for modeling and calculations. Justin also created CAD drawings of the structural elements of the design and added the structural elements into the Revit file. Finally, Justin aided with the research, writing and revision of the MQP report.

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1.0 Introduction:

1.0.0 Design Problem:

Currently, WPI students have had a more difficult time finding collaborative study spaces. They have been using places such as the quad, the campus center, and off-campus apartments to hold serious group meetings. These spaces were not originally designed or intended for this use; however, it has become necessary because of the ever-increasing numbers of new students that are admitted each year. WPI has a need for a revised plan on how to address the limited availability of study spaces.

To further depict the need for improved study space options, WPI has currently enrolled 4892 students (as of fall 2021) which is an 18% increase since 2015. With limited additions to classrooms and study spaces besides the Innovation Studio (introduced in 2018), WPI has still not directly addressed collaborative study spaces in a long time. Students have expressed displeasure in the amount of study spaces for group meetings. Students feel as though there's enough areas for individual study but not for groups. While talking to the Vice President of Campus Planning Facilities, Eric Beattie (Beattie, 2021), he characterized how the next steps for WPI is finding a way to increase the amount of study spaces without compromising other areas of the campus where space is still scarce.

Places such as Stratton Hall and the Project Center seem to be getting less and less traffic simply because of the outdated facilities. Stratton Hall is no longer up to code, with a need for an additional interior egress as well as an elevator to accommodate all students. The Project Center does not see many visitors simply because of the lack of clarity between students of its current use. In addition, the space between Stratton Hall and the Project Center is not used at all and provides nothing but a small cut through to an alleyway near the powerhouse. According to Eric Beattie, what has previously stopped WPI from connecting these two spaces in the past is the floors in each building do not line up and would require some sort of solution to address the split-level feature (Beattie, 2021).

1.1.0. Design Statement and Scope

To address the problems associated with the rising number of enrolled students, it is proposed that an addition to connect Stratton and the Project Center as well as an interior renovation that addresses the need for more study spaces for students should be completed. The addition will include updated systems such as HVAC and plumbing to better improve comfortability for students, sustainability, as well as efficiency so the long-term cost associated with maintaining the building will be lower.

The first step in completing the renovation and addition of Stratton Hall and the Project center will be demolition of the existing interior. Since new layouts will be introduced in both buildings to make it one cohesive space, demolition will be necessary and an ongoing study of all structural components within the buildings was conducted during the course of this MQP. Once demolition is complete, the new design of the building will feature a new entrance from West St. as well as an expanded gathering space on the first floor.

Next, more collaborative study rooms will be located on each floor in the addition. These rooms will provide students with spaces to work as a group or hold meetings with professors. These study rooms, similar to current tech suites in the library, will be used on a reservation basis having their own Microsoft Office compatible device as well as a glass marker board and television.

In coordination with current building codes, it is necessary to design a building that has another form of internal egress as the existing exterior staircase is no longer code compliant (Beattie, 2021). Also, the addition of an elevator that reaches all floors in Stratton is necessary to accommodate all students and faculty. Finally, in order to connect Stratton and the Project Center, it is important to realize that the floor elevations in the two buildings do not properly line up, and a design solution that makes the two spaces one cohesive space is important for the flow of both buildings.

2.0 Background:

2.0.1. Stratton Hall

WPI's Stratton Hall was built in 1894. It originally housed the Mechanical Engineering Department in its early stages. The original designer of the building, Earle and Fisher, designed a space that saw the first and second floors being an open and "undivided space," while the upper floors contained lecture halls, a library, recitation rooms, drawings rooms, a machine design room, and a model room (WPI Tech Bible). The building allowed WPI to expand into other engineering fields as it provided a home for the Mechanical Engineering Department until 1942 when Higgins Laboratories was commissioned.

Figure 1: Current Facade of Stratton Hall

Stratton Hall then was going to change to the home of the Civil Engineering department but in 1943 WPI was selected to become an officer-training school for the Navy V-12 program. The training saw the use of Stratton Hall as the quarters for Navy Seamen until 1946 where then the Civil Engineering Department moved in full-time up until 1954.

After 1954, Stratton Hall housed the Mathematics and English departments. Both departments continued to grow where it was apparent that other space was needed. Now the Mathematics department is the currently the only tenant of Stratton.

More recently, Stratton Hall underwent renovations in 2011. The renovations done in 2011 improved the HVAC on the first floor as well as renovating to create a new computer lab. However, those renovations failed to realize and bring the building up to code as there is a need for an elevator, more overhead fire suppression as well as another means for interior egress (Beattie, 2021) .

2.0.2. Project Center

The Project Center was constructed in 1902. It was originally called the Foundry and served for the production of metal castings. The building was a blend of commercial and institutional purposes. Soon after opening, the Foundry was redesigned to be a high-tech forge shop that would go on to commercially benefit WPI for many years and be utilized by high-profile projects such as those led by Robert Goddard.

Figure 2: Current Facade of WPI's Project Center

Following the introduction of the WPI Plan, which shifted the focus of the institution to project-based learning, the Foundry became the Project Center. It now hosts the Career Development Center and the Interdisciplinary and Global Studies Division.

2.1.0 Construction and Design Consultation:

When designing a new building or facilities it is important to follow the general consultation process so the project that is being proposed will turn out to be an efficient use of resources for all parties involved. The first phase in designing is the pre-design phase.

2.1.1 Pre-Design Phase

This phase is where the architect or builder learns everything about the client, all the general requirements that they want or see in the building space. This information is usually gathered through either sit-down interviews with the owner specifically, focus-groups if the scope of the project is for a general group of people, or a survey if the scope of work is for thousands of people. Things to consider when conducting these preliminary screenings include previous use of the spaces, tenants' lifestyles, proximity to other facilities, as well as similar buildings. This is an important step because without the proper background, the design of the space will not be sustainable, and the use of the building will be discarded shortly after turnover.

Another key aspect in the creation and renovation of buildings are existing conditions. Existing conditions are tracked through old construction documents as well as creating new documents based on the site that work is being done to. For instance, surveying is often used to determine existing ground elevations, property line locations, and measurements of existing structures. Zoning is also a big input in the pre-design phase as any building or structure that is proposed will need to follow the requirements imposed by the town planning board as well as the town's zoning bylaw; this information is usually gathered and placed into a zoning summary report.

The final piece of pre-design involves programs and precedent studies. The building program for a project analyzes the main purpose of the building. Important things to consider when designing a building program include: number of occupants, activities of occupants, functions of spaces, spatial relations, building codes, furniture, and the clients' needs and requirements. The program will provide a basis for design that will be used when creating a floor plan and layout later in the design process.

The main purpose of this proposed project is to join two different building spaces cohesively to not only provide access to all students but also create a new space for students to collaborate. Categories being considered for this new space include, but are not limited to, an elevator, tech suites, computer lab, open study areas, lounge area, and lobby space. These various area types will allow for the main purpose of the building renovations to be achieved.

In addition, when creating a new building or redesigning existing buildings, it is always important to look at precedent studies as a part of the design process. Precedent studies provide a backbone to a new project by applying knowledge gained from past designs to the new one. They can provide inspiration, design concept generation, justification for design ideas, and explanation and communication of project ideas.

2.1.2 Schematic Design

After the background information regarding what is expected for the building is gathered in the form of programs it is then interpreted into a schematic design. The schematic design looks at the general design and shape of the building using the collected data from the programs previously generated. Schematic design typically does not include specifics about materials that are being used (i.e. types of floor finishes, ceilings, wall coverings, etc.) but instead allows the architect to generate multiple designs and floor layouts and propose them to the client. This is the stage where the design is the most fluid and can change very quickly depending on what is requested by the client. At this stage in the design process, the client can get a general feel of how much it'll cost to build the building based on similar previous buildings and a price per square foot. Cost estimates in this stage are very rough and not very detailed due to the lack of detail in the drawings.

2.1.3 Design Development

Design development is where the general structure and look of the building begin to finalize. Clients can always make changes, however, the later the changes are made the more consequences there will be in terms of money and time. At this stage, design specifications are prepared and a more detailed set of drawings, including floor plans, interior and exterior elevations, and sections of the building, are created. The main goal of this stage is to develop a more comprehensive cost estimate by facilitating and engaging subcontractors and using their pricing to determine the general cost of the building by those willing to help build. If the budget of the project is too great, this is the last real chance where the client or owner can make necessary changes to decrease general cost. At the end of this phase, building layouts and dimensions are finalized with most materials being determined. Many times, structural engineers, civil engineers, and MEPs usually join the project and produce their own drawings of what will be needed for the building to be constructed with all the design requirements.

2.1.4 Construction Documents

This phase seems simple; however, it is the longest due to the necessity of getting everything correct and precise. General contractors will look at these drawings and send RFIs (request for information) or RFPs (request for proposal), this is where the design is not clear, information is missing, or the general contractor believes constructability is in question and would rather build it a different way. Once all the specifics are sorted out, the documents are finalized and ready for final subcontractor bidding as well as obtaining building permits for construction.

2.2.0 Building Codes

For this proposed project the main codes that will be utilized are the *780 CMR* (*Massachusetts State Building Code* based on the 2015 IBC), *527 CMR 1.00* (*Massachusetts comprehensive Fire Safety Code*), and the *248 CMR 10.00 (Uniform State Plumbing Code).* These codes provide guidelines that must be followed when creating a new building or updating existing ones in the Commonwealth of Massachusetts.

2.2.1. Egress Implications

An egress is a path from inside a building to an exterior point of safety. Elements of means of egress come in several different forms that include doors, windows, ramps, staircases, and fire escapes.

Although each one of these means of exit can be considered a type of egress, they must meet the required specifications in the city or state of the building. An egress can be broken down into three components: the access, which is the entrance to the point of egress; the exit, the exact method of getting out of the building; and the exit discharge, the location that the point of egress leads to. To ensure a safe and accessible egress, the *Massachusetts State Building Code* has requirements for both size and location of doors, windows, ramps, and fire escapes.

For the Stratton Hall-Project Center project, several code issues regarding acceptable points of egress will need to be fixed. The *Massachusetts State Building Code* requires that when renovations that affect 30% of the building occur, the scope of work has to include improving the building to the code set by the city. Stratton Hall has an exposed central staircase, a fire escape, and a back door that lacks the proper accessibility. By proposing a connection to another building, the work done on the building would make it necessary to include updating all points of egress in Stratton Hall.

The fire escape is the most glaring issue with the egress routes in Stratton Hall. New construction rarely uses fire escapes because they can be dangerous and compromised by weathering. Advancements in fire protection engineering have allowed for safer alternative egress routes from high levels in a several story building.

2.2.2. Fire Protection

The Fire Code exists to protect building occupants from fires by providing mandatory design standards that prevent fire from spreading and allow occupants to exit quickly. Depending on the type of construction (commercial, residential, etc.), fire codes will vary to serve the building as best as they can. A smaller house will not have the occupancy that a skyscraper does, and so enclosed staircases with a 2-hour fire barrier, for example, would not be necessary. There are many forms of fire protection engineering that can be incorporated into the design of a new building. Some examples are fire barriers, sprinklers, closed layouts, fire doors, and egress routes.

Stratton Hall and the WPI Project Center were built prior to the development of modern fire code standards. The two buildings rely on sprinkler systems for fire control and do not have the proper enclosures for points of egress. However, unlike modern designs, the lack of open concept floor plans helps with controlling the spread of fire by providing compartmentation. As part of the redesign process, Stratton Hall and the WPI Project Center will be brought into compliance with current fire codes.

2.2.3 Plumbing and Restrooms

Restroom requirements vary depending on the type of building and the area. If the building is commercial or used as a workspace, there may need to be a certain number of toilets for the number of people that will be using the space. A general estimate of the size and quantity of restroom facilities in larger buildings such as institutional ones like the Stratton Hall-Project Center building can be made based on traffic predictions. With the introduction of a new space increasing the traffic in both existing buildings, there is cause for another look into the restroom capacities.

The *Uniform State Plumbing Code* dictates fixture and piping size and quantities based on the restrooms in buildings. As the two buildings exist, the plumbing is up to code for the current fixtures. The introduction of more restrooms or water fountains will change the standards for the building plumbing system.

2.2.4 Accessibility

Building accessibility is the creation of space that is designed to be user-friendly for all people including those who are physically disabled. These include people with hearing or vision impairments and people who use wheelchairs, motorized scooters, canes, etc. Improving the accessibility of buildings is about removing barriers to promote equality. It affects the whole layout of buildings in terms of flow in the change of elevation, not just at the entrance. Common features that promote accessibility are ramps, power-assisted doors, elevators, and wide doorways.

Stratton Hall and The Project Center were built around the 1900, long before accessibility standards were in place. Therefore, the two buildings have no elevators, lack quality ramps, and have inefficient stairways. The stairways fail to accommodate for students with a disability as well as making it extremely difficult to move hard-to-carry items upstairs or downstairs. A revised plan for student and faculty flow vertically throughout the buildings must also be addressed.

2.3.0 Software for Design and Pre-Construction Activities

The design and construction of a modern building project incorporates many different types of software throughout the entire process. From designing to evaluating constructability to scheduling to cost estimating, the entire pre-construction process is expedited through the use of software.

2.3.1 Revit

AutoDesk Revit is a 3D building information modeling software that can be used to design structures and systems within buildings. It brings together all disciplines of construction from architecture to engineering. It can be used by creating a 2D model of certain components such as floor plans and elevations and then translate that into a 3D model. One key aspect of Revit is its compatibility with other AutoDesk softwares. Revit is compatible with Civil 3D which can directly import and combine accurate site plans into a building design. From this Revit can also generate a simulation of the construction using Navisworks. Navisworks takes the materials and plans from Revit, generates a schedule and simulates each construction phase that the building will undergo until its completion. Not only does Revit aid in construction simulations but it can also aid in energy efficiency and energy analysis by allowing input of site-specific weather and climate data and simulating how the building would be affected by it. Another important feature of Revit is material takeoff. Revit auto-generates a takeoff list of all materials and components of buildings; this is important in order to create a proper cost estimate. Revit is important to ensure that the design and structural components align properly. The group will use Revit to help design and create a 3D Building Information Model of the renovation.

2.3.2 Excel

Microsoft Excel is a spreadsheet software that can be used for a variety of purposes, from performing basic cost estimates by importing material take-off from Revit and associated prices with each specific material to helping determine egress calculations for fire protection. Excel is a multidimensional software that has multiple ways it can be used to do repeat calculations in an orderly manner through the input of set equations and variables. Excel will be used to help organize information as well as determining load, egress, and other calculations for the proposed design.

2.3.3 Bluebeam

Bluebeam is a PDF reader software specifically made for the construction industry. It allows for architects, general contractors, and engineers to collaborate virtually. It allows whoever is using it to do quantity take-off from scaled drawings. This is an important feature, especially when preparing a cost estimate. In addition, it allows the user to highlight and markup specific locations of documents where points of clarity are needed (i.e., RFIs). Bluebeam will be important to use especially when reviewing existing conditions on old construction documents as it allows you to label points of interest.

2.3.4 AutoCAD

AutoCAD is a 3D modeling software that can be used to design various components of buildings. It is typically used to design structural components such as the building foundations, structural beams and columns, and certain HVAC systems. AutoCAD will help model-specific components of any renovation of building construction.

2.3.5 Sage Estimating

Sage Estimating, previously known as Timberline, is a construction software that allows users to estimate the cost of the building based on trades. Typically the CSI *MasterForma*t is used to organize a cost estimate, but in some instances, the *Uniformat* can be used to provide a cleaner cost estimate. To create an estimate, a material takeoff is input into Sage with the corresponding line items associated with trades. Using previous estimates and the Sage database, cost per unit is generated, ultimately creating total cost. Sage also allows users to create estimates based on square foot cost; this is beneficial when drawing details are minimal and detailed material takeoff cannot be performed. Sage will be used to determine the estimated cost of the proposed design.

WPI Students have stated their desire for additional study spaces. Stratton Hall and the Project Center are two long-standing, historic buildings in the heart of the WPI campus. With traditional brick facades and interior layouts, there is precedent for a design that compliments the aesthetic and addresses the fire and ADA code shortfalls, while providing another study-focused area in a central location. Through a general construction consultation, improvements to both Stratton Hall and Project Center will be proposed.

2.4.0 Seismic Considerations

When connecting the Project Center and Stratton Hall, there is concern for shear transfer between these connecting faces. The proposed addition will be a steel-framed structure, while the existing buildings are aged masonry structures. The proposed addition is quite dissimilar from the two adjoining buildings, and there is a concern for the seismic loading if the buildings are connected. The seismic responses will not be the same. Aggressive movement can crack the foundations and create instability.

To mitigate shear, seismic joints are used to connect structures. Often times when two buildings are built adjacent to one another, the seismic joints will be used as accommodating space passages for electrical, HVAC, or plumbing that might be crossing between buildings. Ultimately the purpose is to allow the movement of one structure to have a reduced impact on the neighboring structure.

3.0 Methods and Deliverables:

The goal of this project was to create a space that successfully encompasses the needs for private conference areas for both the students and faculty. Generally speaking, construction consultants follow an established format from the pre-design phase to the construction phase in order to properly account for their clients' demands and needs. *Figure 3* shows the project timeline of a typical design/build firm.

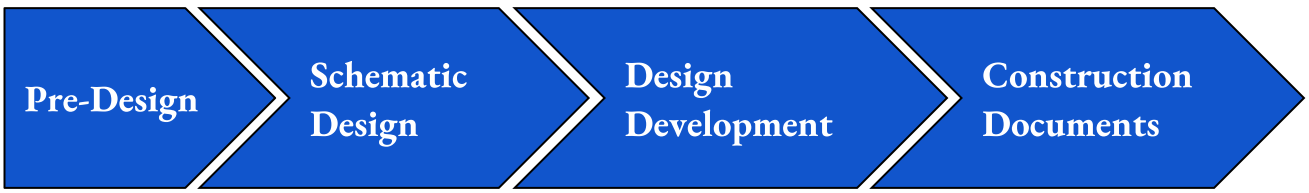


Figure 3: Overview of general timeline for design/ build firm

Most buildings that will be proposed for completion typically occur at the end of the schematic design phase or at the beginning of the design development phase; this is where the owner can typically see the whole project coming together. To properly propose a renovation and connection between Stratton Hall and the current Project Center, most pre-construction work, except for bid solicitation, was completed to determine efficacy. The objectives and methods to achieve the project goal are shown in *Figure 4*.

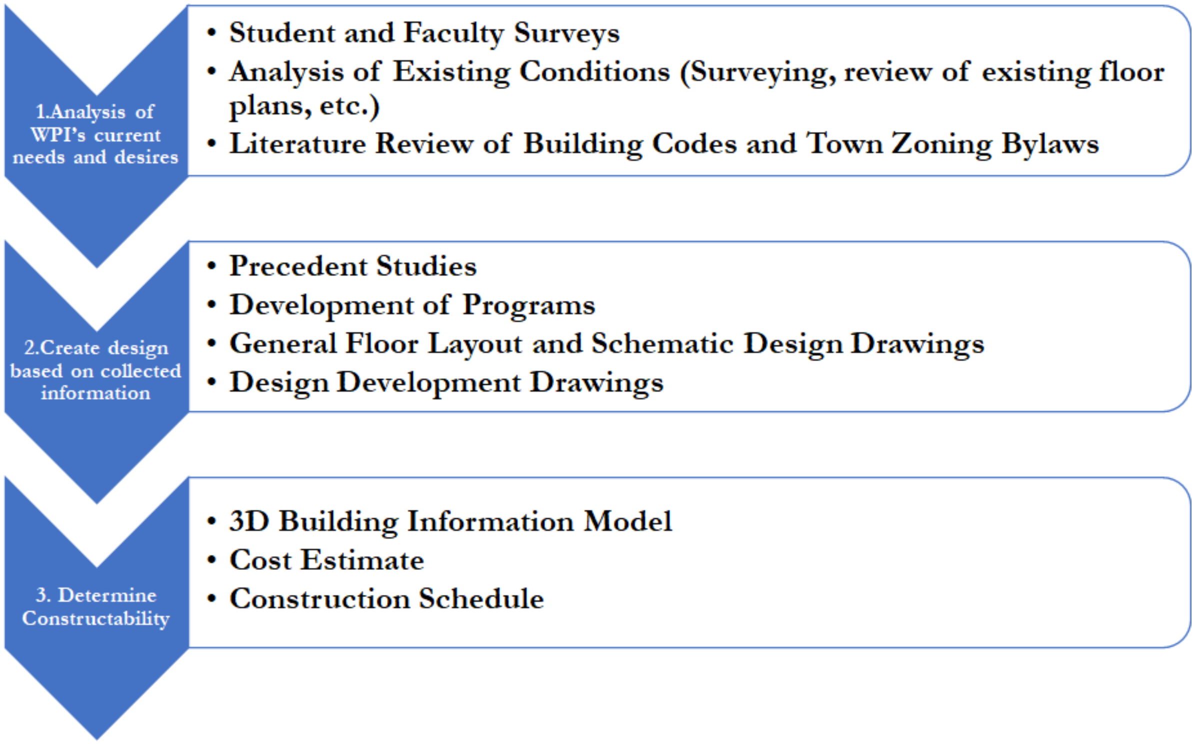


Figure 4: Overview of Project Objectives and Methodology

3.1.0 Pre-Design

The first phase in any construction is pre-design. Pre-design encompasses the whole scope of the project, from who the project is being built for, to the interpretation and analysis of existing conditions and zoning bylaws, to what are possible design options and or criteria of the project. For the purpose of this project, an initial survey of students and faculty was completed to gauge interest and determine what they want from the space, then a comprehensive analysis of existing conditions and zoning bylaws was conducted, followed by the creation of programs based on precedent studies and previous data.

3.1.1 Survey

The first step in developing a proposal for construction is determining what is desired by the clients. In the case of Stratton Hall and the Project Center, the clients were WPI, including current students and faculty. The goal for this project was to create a space that all students desire or feel the need to have based on the current climate around campus. To gauge the general interests of WPI students a survey was conducted. The survey asked students about the general experiences related to Stratton Hall and the Project Center, current availability of study spaces, desired locations of study on campus for both group work and private study, and a brief analysis of which academic buildings they feel could be improved on or modeled after (i.e., the layout of Gordon Library). The survey was made on Google Forms and was distributed to local organizational message boards as well as made available throughout campus, via a QR code, for students to answer at their convenience. *Table 1* presents the list of the questions that were asked to students.

Table 1: List of student survey questions.

Have you personally had classes in Stratton Hall?
Have you personally been in the WPI Project Center located next to Stratton?
If you needed a place to study on Campus for an exam or project work where do you go?
If you needed a place to study in a group on Campus for an exam or group project work where do you go?
Do you have difficulties finding spaces to study?
Is there any space on campus where you see a need for improvement in terms of flow, accessibility, comfortability, etc. ?

The survey process for faculty input was similar to that for the students. They were asked questions related to any improvements that they see or desire for the campus to have shortly, as well as more specific questions for those instructors who have been relocated due to the renovations in Kaven Hall to determine the impact and effect it has had on them and their productivity. The list of faculty survey questions is presented in *Table 2.*

Table 2: List of Faculty Survey Questions

Is there any space on campus where you see a need for improvement in terms of flow, accessibility, comfortability, etc. ?
If a renovation to Stratton Hall and the Project center were to happen, what do you want to see in the space?
Were you affected by the ongoing renovation to Kaven Hall? If so, can you talk about your experience? (How has it impacted your productivity? Is there anything WPI could have done better to mitigate the effects of having to relocate classes and personal offices?)

The data collected from both sets of surveys was then gathered into one Excel file and interpreted to identify common connections between students and faculty, with the goal in mind of creating a program from their shared responses.

3.1.2 Existing Conditions

To design an addition or a renovation to a building, existing conditions must be examined. There is information such as elevations, HVAC and plumbing locations, dimensions, and many others that cannot be overlooked before construction begins. There are two locations where documentation of the Project Center and Stratton Hall is stored: The WPI Library Archives and WPI Facilities. Available drawings were obtained for both buildings, whether they are original or for renovation plans, as they showed some of the necessary information for input to the design and calculations. Another method of examining the existing conditions is by physical survey. This helped us specifically determine the exterior data such as the total distance data and the elevation data of the Project Center and Stratton so that the new addition could be aligned correctly with the two existing structures.

3.1.3 Zoning and Bylaws

Before making any renovations or additions to a building in the Worcester area, one must first seek approval from the city and more specifically the city planning department and eventually the City of Worcester Planning Boardl. The City keeps track of all land parcels and the additions and changes to them. The Planning Board assures that building plans are safe and up to code before any work is completed. The City of Worcester zoning ordinance states that "No building, structure or land, in any district, may be used, erected, altered or expanded, in whole or in part, for any use not expressly permitted in that district unless as a permitted accessory use pursuant to Article IV, Section-8." This means that unless it is not zoned for the proposed use, review by the city council is not needed. In order to adhere to current zoning, a literature review was done discussing the current zoning of the proposed construction.

3.1.4 Special Conditions

This proposed project will include many unique design aspects that will require custom work in order to complete the goals of the project. The top of floor locations for the two buildings are at slightly different elevations. This means that the created section between the two buildings will have to find a way to accommodate the differences in floor elevations. This will also include finding a way to give elevator access to all floors of both buildings. Another issue specific to this project is the electrical, plumbing, and HVAC systems. Since each building has its own respective electrical, plumbing, fire and HVAC systems, the newly installed systems for the proposed connection will need to be connected to either one of the buildings or be an independent system.

3.1.5 Precedent Studies

Precedent studies serve as an inspiration for building design in the pre-design phase. In order to find relevant precedent studies, different aspects of the project were selected to focus on. The two main categories for research that were looked at were connecting existing buildings and different types of group study spaces. These categories were selected because, along with making these buildings accessible, one of the main purposes to connect Stratton Hall and the Project Center is to create a new study space on campus where students can meet and collaborate with their team. Various buildings were looked at during research, taking into consideration a variety of factors, including the social and cultural aspects, the geometric form and mass of the building, the purpose of the building, and the building materials.

3.1.6 Building Program

In order to build a program, background information was gathered. This information included the results from the student and faculty surveys, the precedent studies, the client's needs, and the building requirements. The building requirements combined with the client's needs dictated the types of spaces that were put into the program.

3.2.0 Schematic Design

The next phase in any construction consultation would be the creation of schematic design documents. The schematic design typically includes some sort of exterior rendering and floor layouts. Costs can be estimated from these plans, but they are limited by using prior estimates. Schedules can also be created.

3.2.1 Floor Plan

When designing the floor layouts, the previously created program was utilized to provide a backbone for various floor plan layouts. Along with the program, the generated layouts defined the functional spaces, enabled good flow between spaces, and complied with the building code. Taking all of this into consideration, the group collaboratively designed multiple floor layouts per floor for the whole building to compare different possibilities. These designs started off as hand sketches based on the program, and then Revit was utilized to provide more precise and in-depth layouts. As a group we then analyzed the benefits and setbacks to each layout in order to decide which of these layouts best met the client's needs. The floor layout that was decided on was selected for the schematic design floor plans for the project.

3.2.2 Elevation Plans

To design the addition, we needed to determine the floor elevations on each of the existing structures. If there are differences between the floor elevations, then that would affect the floor plans. The elevations were mapped with two methods. First, the existing drawings were examined. Although sparse, WPI has some copies of exterior drawings that include elevation cuts with dimensions. The second method was surveying. Surveying tapes were used to look at the elevations of Stratton and the Project Center from the exterior. This method also helped verify the accuracy of the drawings.

However, it was difficult to get accurate floor elevations due to the total station needing to be outside to properly function. Therefore, an additional method was used in which the height of the windows on the outside of the building were measured using the total station or another measurement tool, the distances from the floor to the window sill on the inside of the building were measured, and then those interior sill heights were subtracted from the external window elevations to get the most accurate floor elevations.

3.2.3 3D Modeling

From the floor plan generated from the design development drawings, a 3D model of the connection between Stratton Hall and the Project Center was created. To generate a 3D model, Revit was utilized. Building materials were selected based on the existing materials within Stratton Hall and the Project Center as well as incorporating the information gathered from the precedent studies. Finishes for the general materials used throughout the building differed; for example, different flooring materials ranging from carpet, tile, and concrete. Materials for finishes were later selected based on newly renovated buildings on campus, including Unity Hall, Kaven Hall, and the Innovation Studio. Revit also generated a list of materials that later helped with the general cost estimate of the building.

3.2.4 Fire Protection

As part of the renovation process, the fire protection features including fire walls, fire barriers, fire doors, sprinkler systems, and egress all had to be included. As the floor layouts and 3D model were evolving, fire protection features simultaneously were changed. Some fire protection features, such as fire barriers and fire walls were moved or added as design changes were made to the floors. All of the fire protection features that are included were researched using the *Massachusetts State Building Code* and the *Massachusetts Fire Code* to ensure fire safety throughout the building.

3.2.5 Egress Analysis

In order to complete an egress analysis for the building, after the floor plans were finalized, each room was designated with an occupancy type according to its use. Each occupancy type has a corresponding occupant load that can be found in Table 1004.1.2 of the *Massachusetts State Building Code*. The given occupant load and calculated room size are used to determine the total occupant load per floor. Once the occupant load for each floor was determined an analysis can be done to make sure the egress provided is sufficient for the load. For this part of the analysis, the given stair and door width is used along with use factors that go with each. These factors can be found in section 1005.3.1 for stairs and 1005.3.2 for doors, ramps, etc. These factors are used to determine how many people can use the exit given the width of it. This factor decreases for sprinklered buildings, which increases the occupants that are allowed to use each exit. Performing an egress analysis determined if the buildings egress is adequate for the total occupant load.

3.2.6 Scheduling

Once the 3D model and floor layouts were finalized, information gathered from previous building schedules for renovations and new building construction and renovation on campus, such as the Bartlett Center, was used to create a comprehensive list of activities that will be needed for construction. The list was then assessed and scaled down to meet the size of the new building using a general estimation of duration when possible. Some activities remain the same length and some change depending on the scope of work.

The schedule also included selective demolition of portions of Stratton Hall and the Project Center, as well as other site-specific tasks. The schedule displayed the total duration of the project from demolition to final punch list items.

3.2.7 Cost Estimate

Similar to the schedule, the cost estimate was dependent on the materials used in the 3D model as well as the general floor layouts that were finalized. As previously mentioned, Revit generated a material takeoff list of all the materials that were used; however, this did not include all the necessary materials for construction. Using the schedule in combination with previous estimates, a general idea of what needs to go in the building was included as well as general allowances for items such as emergency signage, or demolition that aren't explicitly outlined or easily quantified in the plan. For this reason, Sage Estimation was used. Sage allowed us to take the material takeoff from Revit and enter it directly by just assigning a price per unit. All other items were inputted as well for the entire structure. The cost was not just for the materials but also for the installation and general contractor fees as well as other back-page items in the estimate.

Our final deliverables included the floor layouts, the 3D model of the renovation including fire protection features, an egress analysis, a construction schedule and cost estimate, as well as a general analysis discussing constructability.

4.0 Results

4.1.0 Pre-Design

4.1.1 Survey

The initial survey of the WPI student body provided a chance to gain some insight into what students currently experience in regards to the existing conditions of campus as well as possible shortcomings of the current design of the campus. The survey highlighted the multiple areas where students currently study individually and in groups as shown in *Figures 5 and 6*, respectively. The tables shows that the library is the primary building layout that should be used for inspiration.

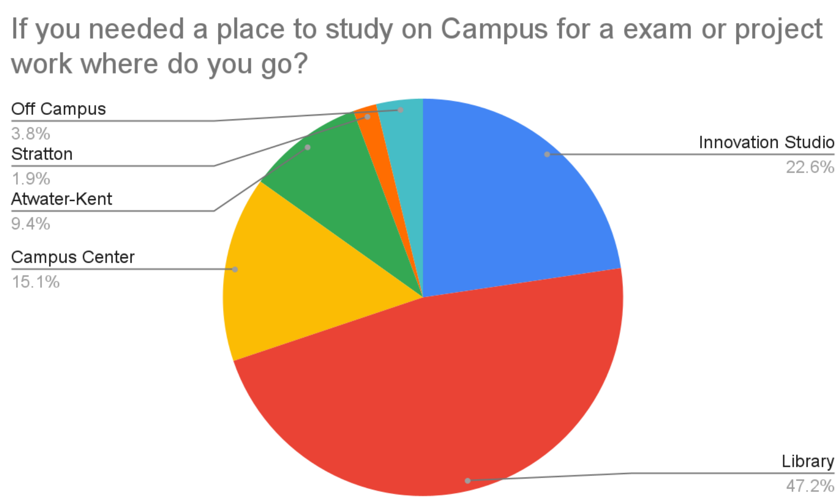


Figure 5: Pie-chart of Students' Desired Places to Study

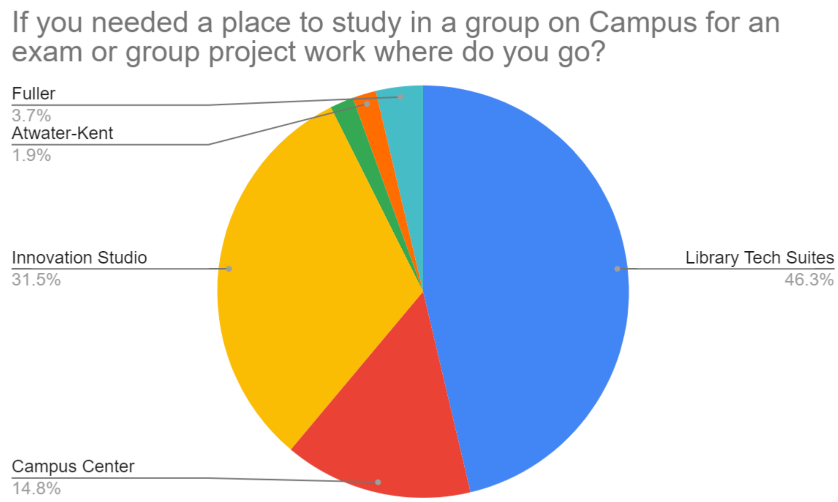


Figure 6: Pie-chart of Places Where Students Work in Groups

To further evaluate the current climate in which students operate, a more direct question was asked of whether or not it was easy for students to find study spaces. Nearly two-thirds of the students that responded to the survey shared how they believed that there is not an adequate amount of open study spaces for all types of study around campus as shown in *Figure 7.*

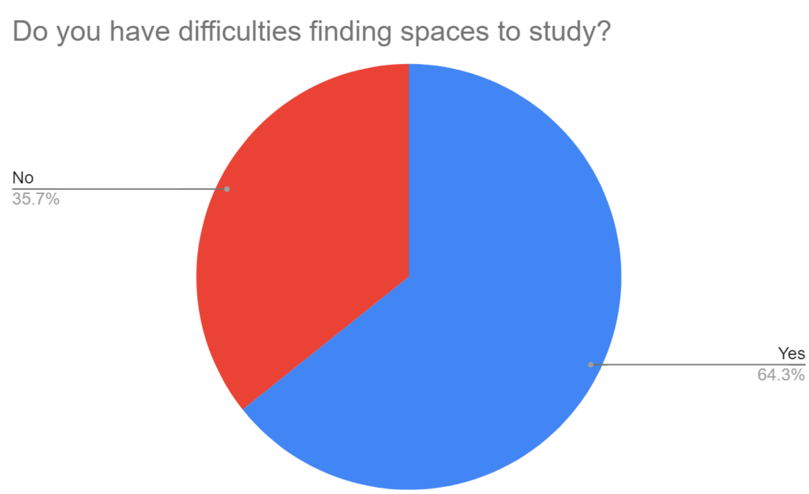


Figure 7: Pie-Chart of Students' Difficulty to Find Study Spaces

The survey also provided students a chance to voice their opinions on what recommendations they would give in order to improve and promote flow, accessibility, and comfort across campus. Multiple students addressed Stratton Hall as one student specifically stated that "Stratton definitely needs at least an elevator" and continued to elaborate as it is difficult and not accommodating for students that have disabilities or are injured. Students typically looked at the general picture of the entire campus rather than paying attention to specific details about certain buildings. Multiple students outlined how there is a need for more outlets throughout all study spaces on campus as well as a need for "More tables and seats in all academic study spaces…as it can be hard to find places to do work. Also places with outlets are very difficult to find." Similarly, another student further related and said, "There is a lack of availability of outlets…It's always hard to find a study space especially during midterms and finals week." Any newly designed space will need to ensure that there are enough outlets to accommodate all students and tables.

Students also provided recommendations on how construction should be organized to maximize efficiency. One student suggested that the "library is an excellent template for campus construction. One floor for silent study, one floor for mostly silent study, and another floor for loud talking. All three floors have group workspace in both open and closed rooms with whiteboards and computers." This suggestion was highlighted throughout the initial part of the survey as it saw the library as the preferred space for study. Students also characterized displeasure with the current set-up of the Innovation Studio. Following a format similar to the layout of the library will be beneficial to any space that is designed between Stratton Hall and the Project Center because it will be socially accepted and welcomed by the student body.

4.1.2 Field Data

In order to determine the heights of the floors in both Stratton Hall and the Project Center, surveying tapes were used to measure as many data points as possible. The table below displays those measurements.

Table 3: Field Recorded Data Used to Determine Floor Elevations

Feature	Dimension (ft)
Distance between Stratton Hall and Project Center in the front (West St.)	26.1
Distance between Stratton Hall and Project Center in the back	25.8
Width of Stratton Hall and the Project Center (individually)	52
Height from 3rd story windowsill to the ground (3.5' floor to sill) in Stratton	38.2
Height from 1st story windowsill to the ground (3.8' floor to sill) in Stratton	11.2
Height from floor to sill in the bottom floor of Stratton Hall	5.1
Height from Stratton Hall fire escape door to ground	7.2
Height from Career Development Center (CDC) exterior side door to ground	6.11

4.1.3 Existing Conditions

The existing conditions of Stratton Hall and the WPI Project Center are broken down into dimensional components and physical features. Table 4 shows the interpretation of the field data in Table 3, to get the relevant data for our Revit models. The numbers were extrapolated from the measurements that were obtained using a surveying tape.

Table 4: The Relevant Elevations for the New Building

Feature	Dimension (ft)
Stratton Hall 3rd Floor Elevation	34.7
Stratton Hall 2nd Floor Elevation	21.05
Stratton Hall 1st Floor Elevation	7.4
Project Center 2nd Floor Elevation	21

To better see the entire space available to build an addition that would connect both Stratton Hall and the Project Center, a 3D model with the top of floor elevations that were determined for each building was created in Revit. The model is shown in *Figure 8* and *Figure 9*.

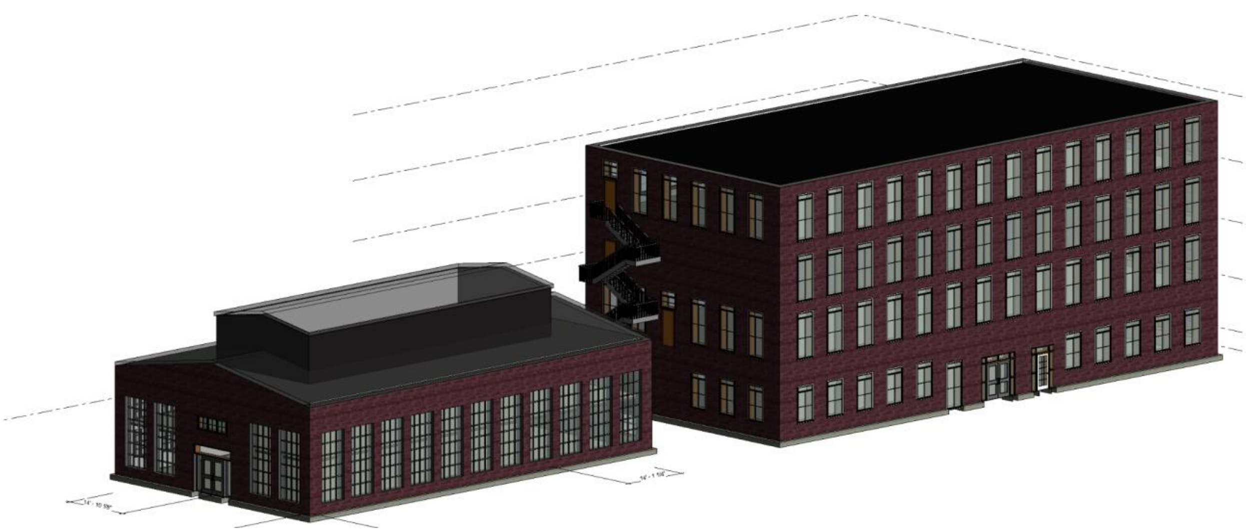


Figure 8: Revit Model of Existing Conditions of Stratton Hall and the Project Center

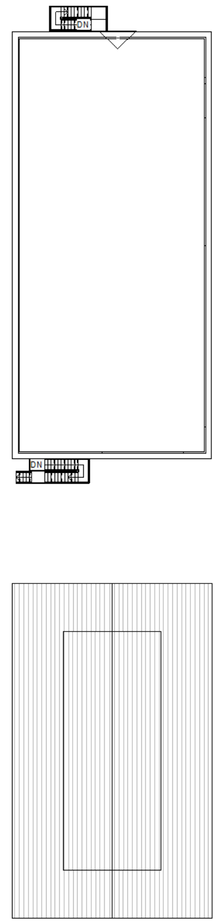


Figure 9: Site Plan View of the Existing 52'x 26' Space in Between the Project Center and Stratton Hall

4.1.4 Zoning Bylaws

According to the City of Worcester Zoning Map, the entirety of WPI's campus is zoned as IN-S which means it is supposed to be used as an Institutional space, specifically for education. This zoning designation allows a lot of freedom to what can be built. Consequently, for this proposed building, there is no need for any special permit to perform a renovation that includes general research and office spaces. The general requirements for building dimensions in the Worcester City Zoning Ordinance are because there are no requirements for frontage as well as building heights for all uses in Institutional zoned parcels. The only requirements to consider are minimum yard setbacks of 15 feet for the front yard and 10 feet for the side yard and the backyard. This will not be an issue as the location of the proposed renovation is directly in the center of WPI's campus.

4.1.5 Precedent Studies

For this project, two precedent studies were consulted to account for the connection of various buildings and the combination use of classrooms, offices, and study spaces on a college campus.

The Indianapolis Skywalk connects the Indianapolis Convention Center to twelve hotels, various restaurants, stores, conference rooms, and even a stadium. It is the largest connection of its kind in the United States. The connection creates a social hub for interaction between people and businesses. It provides a space to decrease traffic congestion on the busy city streets and a warm way for people to get around in the winter months. The main convention center is connected to various hotels, restaurants, and shops via multiple interior bridges that make up the skywalk, which is shown in *Figure 10*. These interior bridges are rounded glass tunnels with steel that allow for natural light to come in as well as the people using them to not lose the view of the city surrounding them. This is shown in *Figure 11*.

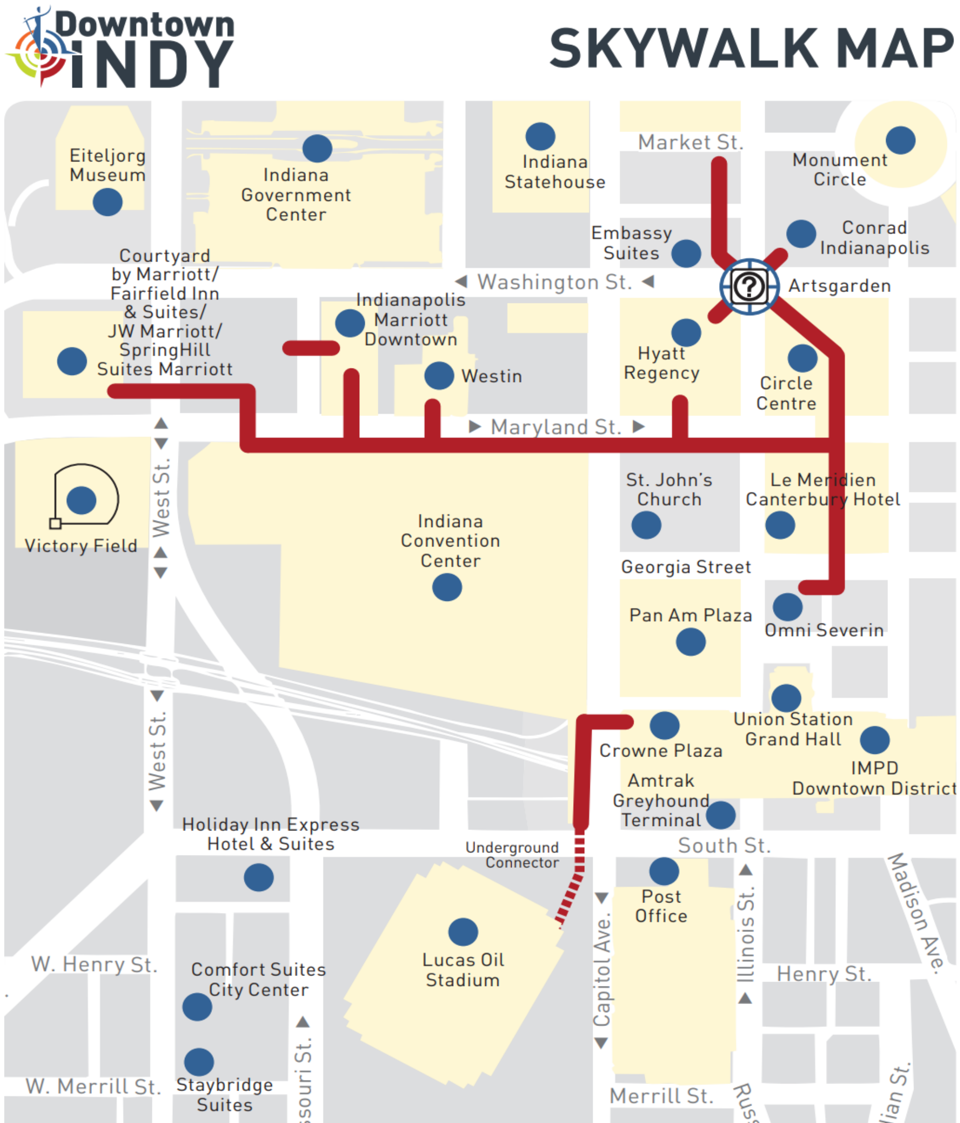


Figure 10: The Skywalk Indy Map (taken from Indianapolis 2021)

Figure 11: Top View of Connecting Glass Hub (taken from Indianapolis 2021)

Being such a mass construction, the skywalk provides a large-scale application of building connections. This idea can be applied on a smaller scale and used for the connection of Stratton Hall to the Project Center on the WPI campus. This could help accommodate the differences between the top of floor elevations for the two buildings while still providing accessibility between the two buildings. From an aesthetic viewpoint, a glass connection could help with the clashing facades of the two current buildings. It can also provide more space for students to meet with each other to work on group projects and homework, creating a new social hub on campus to support student interaction and growth.

The University of Portland Clark Library was originally built in 1958 (shown in *Figure 12*). In May of 2012 renovations began to the building in order to bring it up to date with modern times. It reopened in August of 2013. It is a 56,000 square foot area that includes 20 group study rooms, five booths, and twelve individual study carrels. The goal of the renovation of the Clark Library was to create a space to foster the highly collaborative way students work and learn today. This is because the school noticed a need for spaces where students could comfortably and collaboratively work, study, and hang out together.

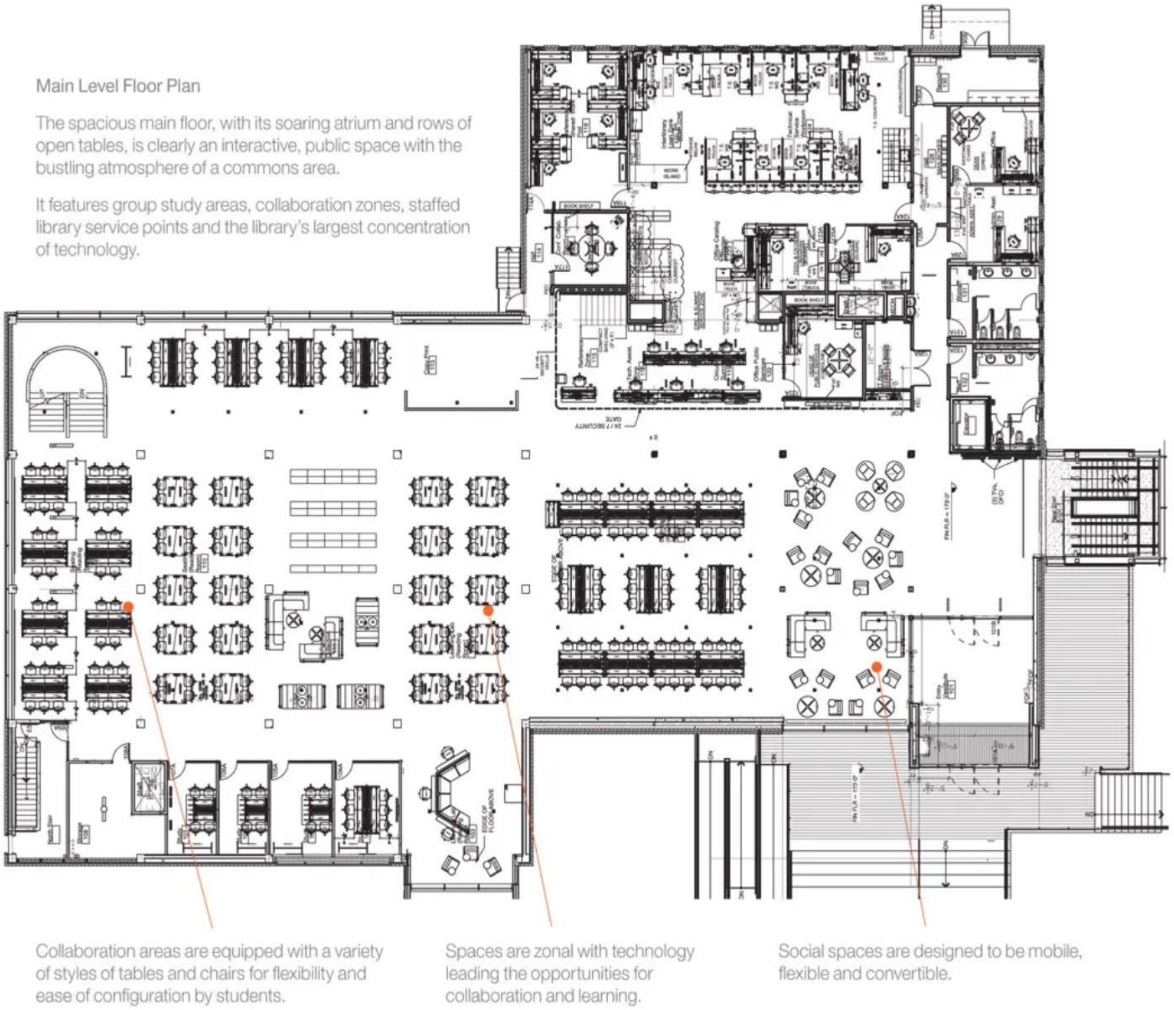


Figure 12: Main Level Floor Plan of Clark Library (taken from Knoll 2021)

WPI is currently faced with a similar issue, due to the rapid increase in students on campus in recent years. Students are met with a lack of private collaborative study spaces to conduct group work. As a part of the renovations to Stratton and the Project Center, the addition of varying study spaces will be included in order to help meet this need on campus. The varying studying spaces that the University of Portland Clark Library included in their renovations will be used as a guide for the types of study spaces that can be included in the new academic space being created.

4.1.6 Program

Based on the results from studying the existing conditions on campus, it was identified that there was a need for more group study spaces. When creating the program, the needs of the students, the existing conditions of the buildings, and all relevant building codes were taken into consideration. The program includes various spaces in order to meet these needs including tech suites, open study spaces, offices, a lounge area, restrooms, an elevator, and a staircase. Keeping in mind the existing conditions of the buildings, the program for each floor was defined so relative noise lessens with each ascending floor. This mirrors the layout of WPI's Gordon Library as the lower floors in the library have less foot traffic and were therefore designated as quiet study spaces. As per the results of the survey, students found the layout of the library quite appealing so it was decided that something similar would be extremely beneficial. Due to the predicted higher foot traffic on the first two levels of the new addition, where the Project Center and Stratton Hall both connect, these floors were designated for more open and collaborative spaces where noise from groups will be more tolerated. The two uppermost floors of the new addition are intended to provide more of a quiet study space where groups and students can have more privacy since there will be less foot traffic as the addition will be only connected to Stratton Hall on these floors.

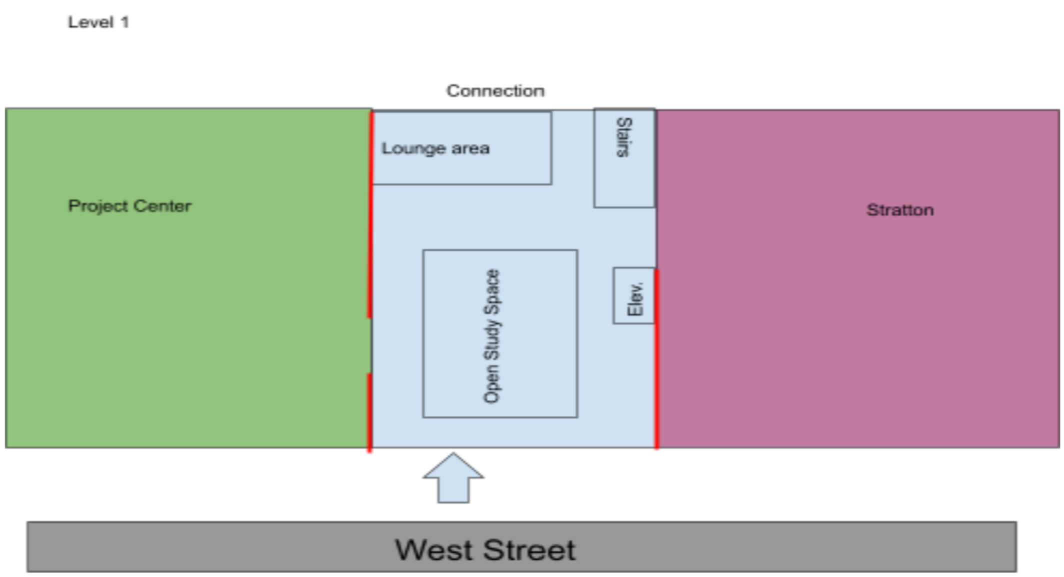


Figure 13: Program Level 1

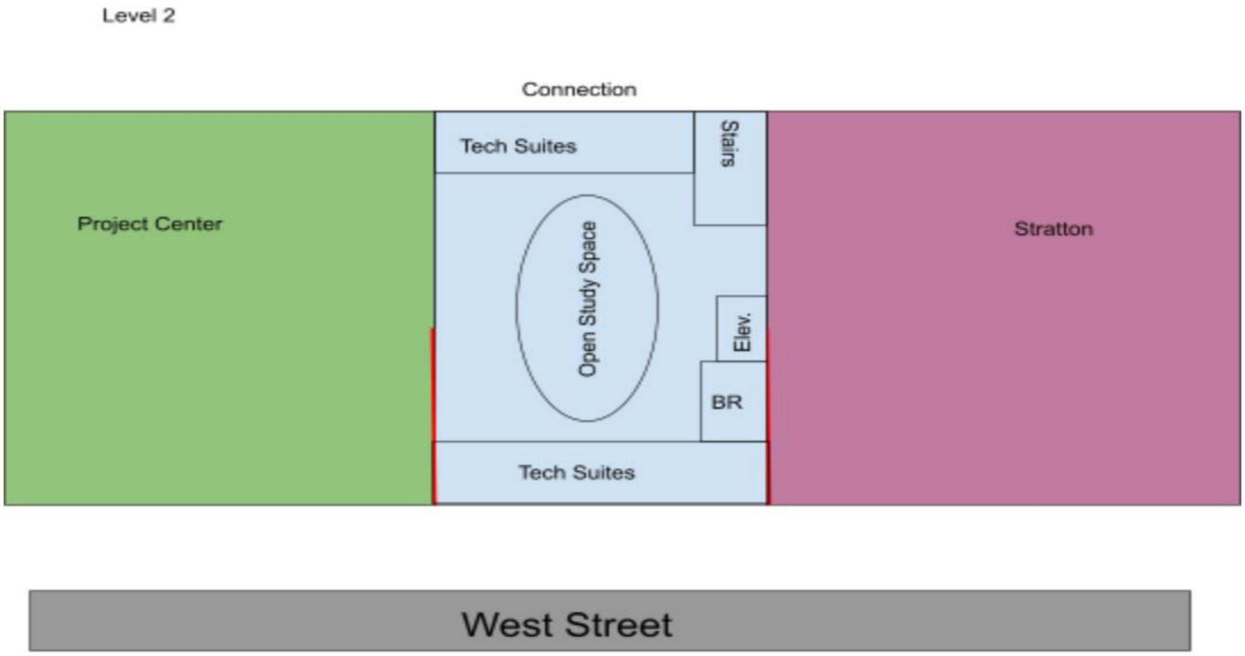


Figure 14: Program Level 2

Figure 15: Program Level 3

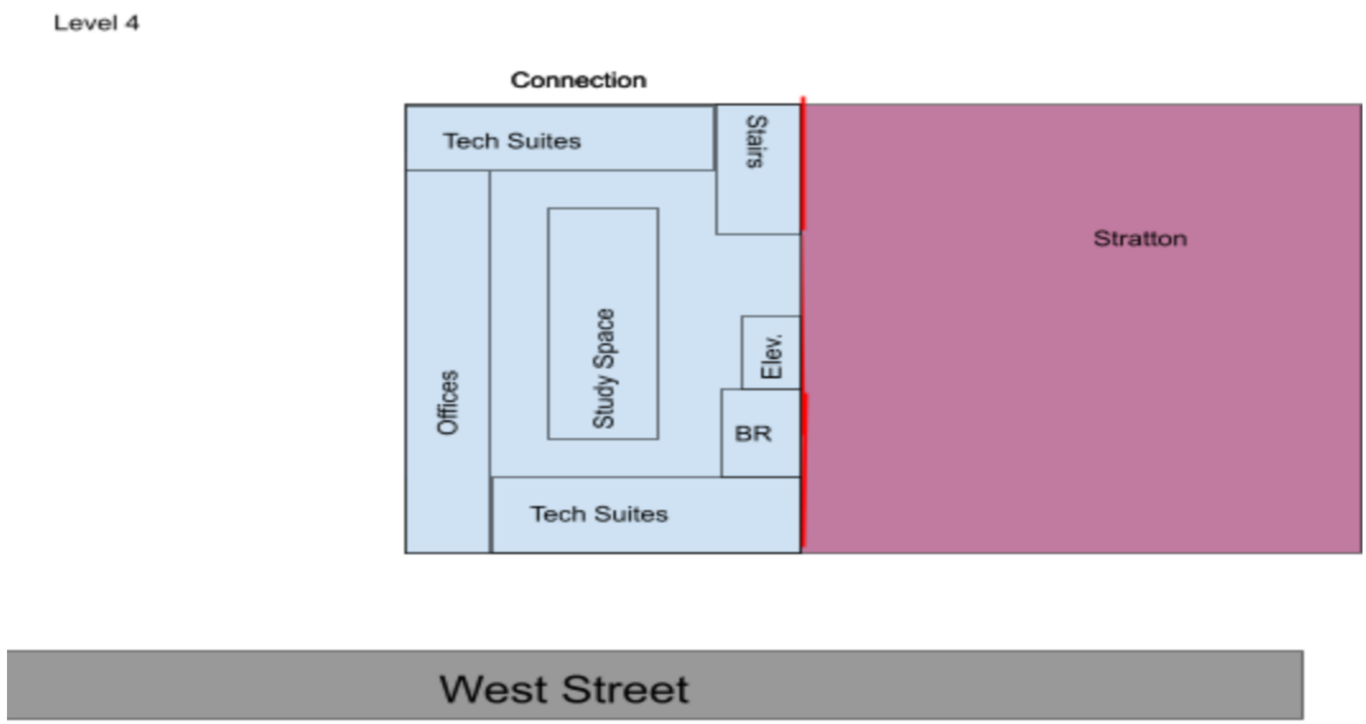


Figure 16: Program Level 4

The main form of requested space for group work on campus is tech suites. Currently, tech suites are hard to come by because they are in high demand as well as difficult to reserve. The building program for the proposed connection includes multiple tech suites varying in size, which can accommodate groups from three to ten people. The increase of tech suites on campus allows for more groups to reserve a space for project meetings and study sessions.

As shown in *Figures 13 and 14,* the first two floors have a large portion of space designated for open study space. These spaces will allow for a more casual meeting area where groups could gather, or students could work individually. The first two floors of the addition will provide alternatives for students who currently resort to doing work in the Campus Center at the tables within the food court.

Offices for professors were included on the fourth floor of the program design, *Figure 15*. As a part of the renovations within Stratton Hall, some professors' offices will be displaced to account for a seamless transition between the proposed addition and Stratton Hall. Relocating these faculty offices to the top floor of the connection will provide a quieter area for professors to meet with students and colleagues, and to complete their work.

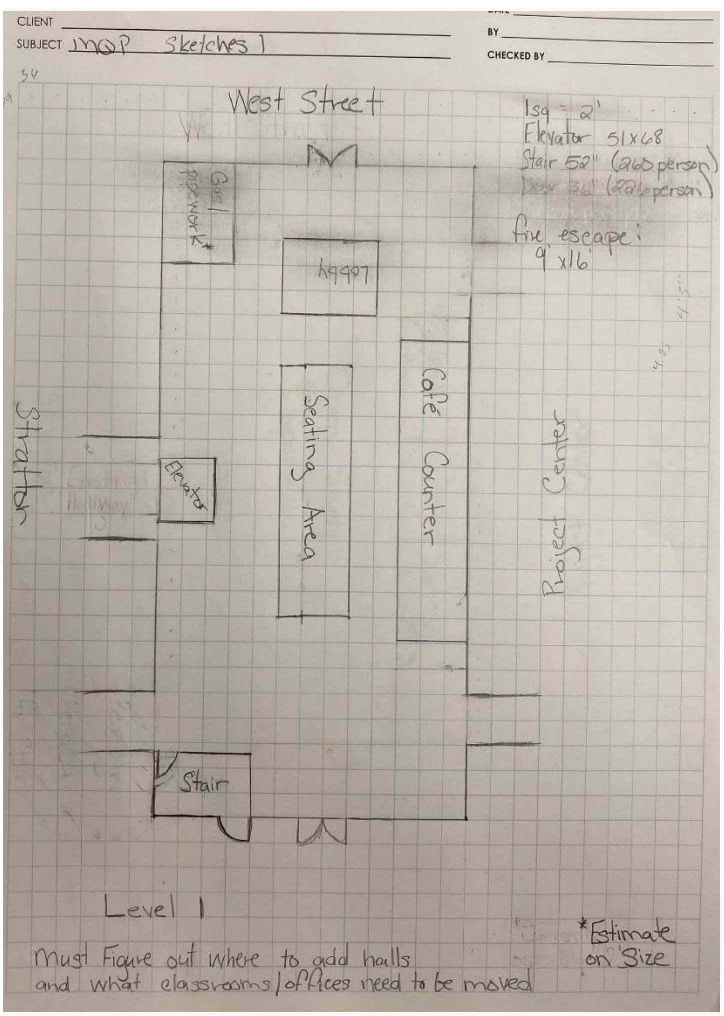
Gender-neutral, single-person restrooms were also added within each floor of the program. The increase in restrooms is to accommodate the increase in students in the building. Using gender-neutral, single-person restrooms make it easier for students in any of these spaces to find a restroom they can easily access on their floor since the restrooms in Stratton Hall alternate genders per floor.

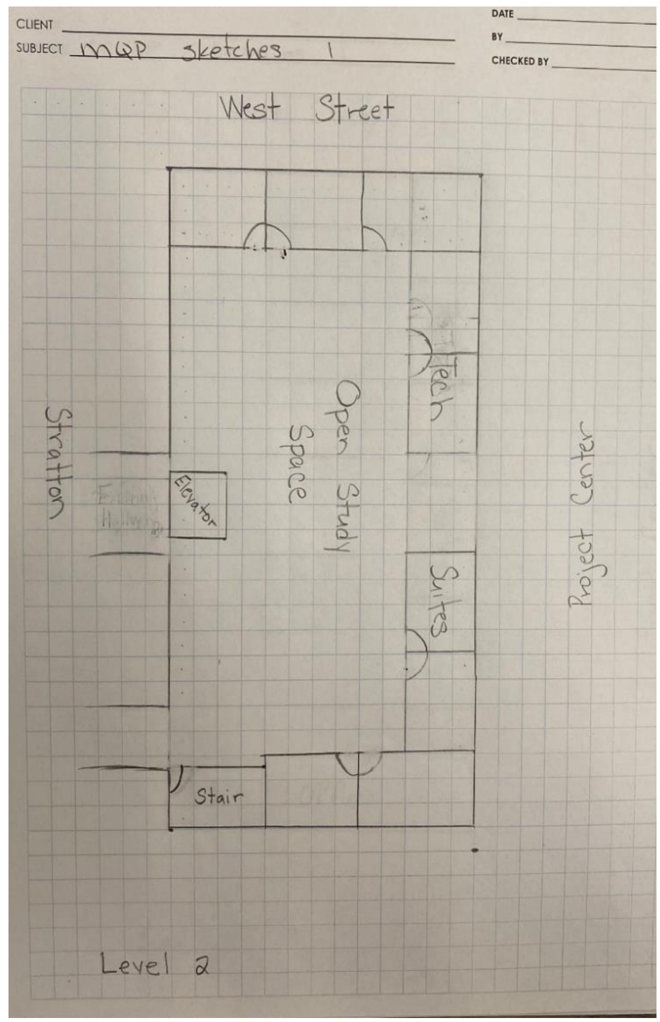
One of the main requirements that was discussed with Eric Beattie of the WPI Facilities Department is that a proposed connection between Stratton Hall and the Project Center must have an enclosed staircase as well as an elevator (Beattie, 2021). The addition of an elevator will allow for all members of the WPI community to be able to access the resources provided in both buildings as well as the connecting area. The new staircase that was included in the program will replace the fire escape that is currently on the exterior of Stratton Hall. The proposed staircase will be able to accommodate the increase in persons in the building and will provide proper egress from the buildings to a safe point outside of the building. The inclusion of these two key components will bring the buildings up to code with accessibility requirements.

4.2.0 Schematic Design

4.2.1 Floor Layouts

When beginning floor layout designs basic layout ideas were explored for each floor. These drawings took into account the existing condition of gas pipes located on the side of Stratton Hall. This created an awkward cutout on the first floor of the building so an alternate design that relocated the gas lines was later created. The first set of floor layouts also looked at the new building as its own structure and did not take into account where current hallways, doorways, rooms, and exits are in the existing buildings. Instead, hallways were drawn in where they could possibly be located to create the best flow from one space into another. A problem that was discovered in the drawings was that the size for the new stairway was incorrect -- the added stairway was too small to accommodate the space – and it was updated in the next set of drawings to a proper size. Moving through the floor spaces, the first floor was created to be an open space with the idea of having a cafe perhaps, to draw in more students to the space. On floors 2 through 4, there are tech suites varying in sizes, open study spaces, offices, and a computer lab. The tech suites designed in these first sketches were not all-sufficient sizes for groups to meet in. Measurements of different-sized tech suites located throughout campus were taken to use as a size guide in the next set of drawings.





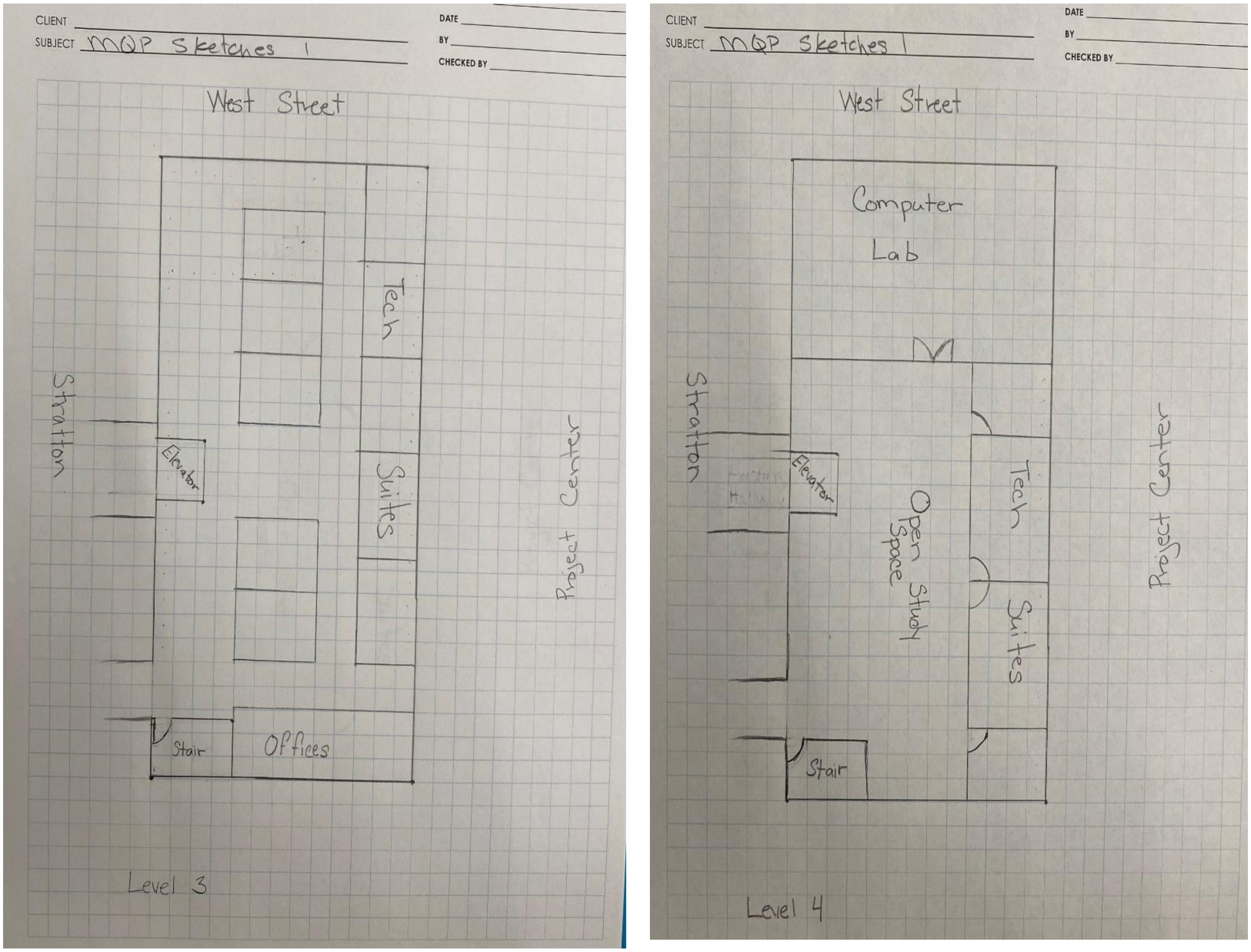
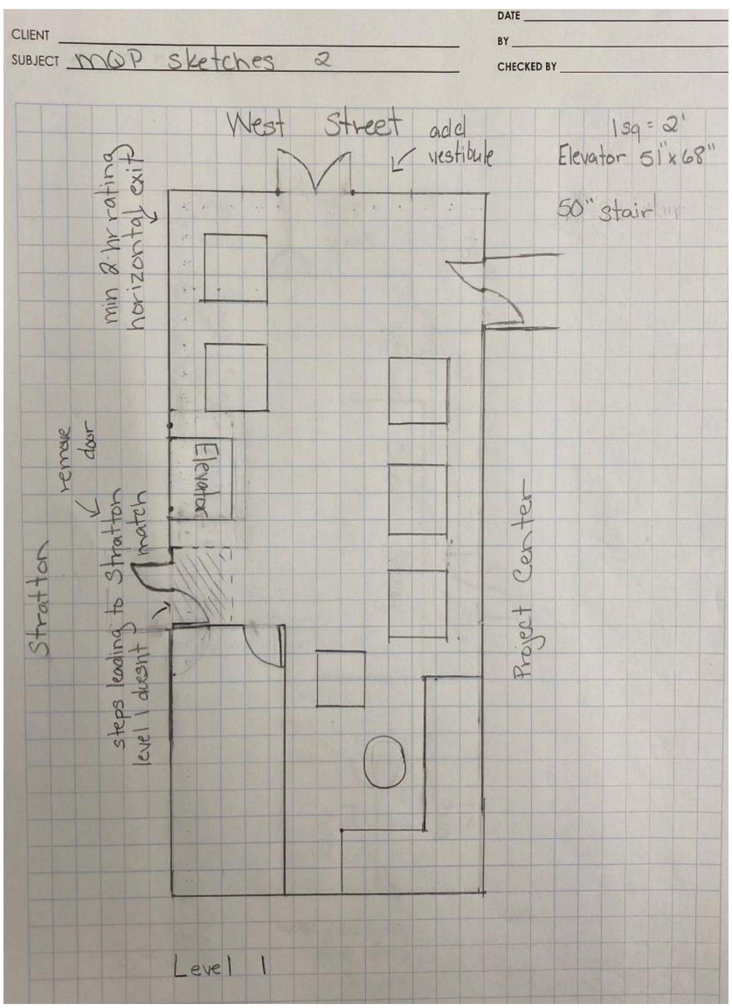
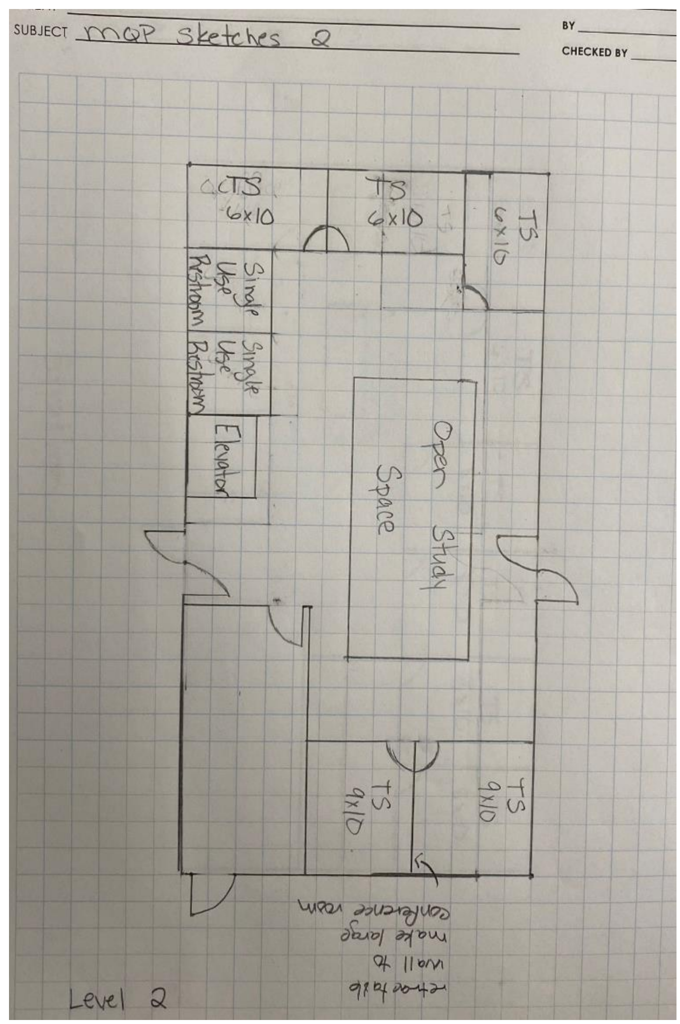


Figure 17: First Set of Floor Layout Sketches

In the second set of sketches updates were made to address the problems with the original drawings. This included updating the stairway to make it the proper size and relocating the gas meter for both the Project Center and Stratton Hall to the West Street side of both buildings to resolve the awkward cut-out in the corner. The cafe was eliminated altogether in order to provide more open study space for students to work. A lounge area was included in the backspace in order to provide a more relaxing and inviting area for students. Hallway locations changed as they were added based on the location of the existing building's hallways. The tech suites on the upper floors were resized, considering the information gathered on existing tech suites on campus. More office space was added as well to account for the conversion of existing offices in Stratton Hall into a hallway with access to the new elevator. On the fourth floor, the Computer Lab was ultimately deemed less necessary and was replaced with more tech suites. Finally, a single-use restroom was added to each floor to provide all students a more accessible option compared to the existing conditions in Stratton where male and female restrooms are located on alternating floors.





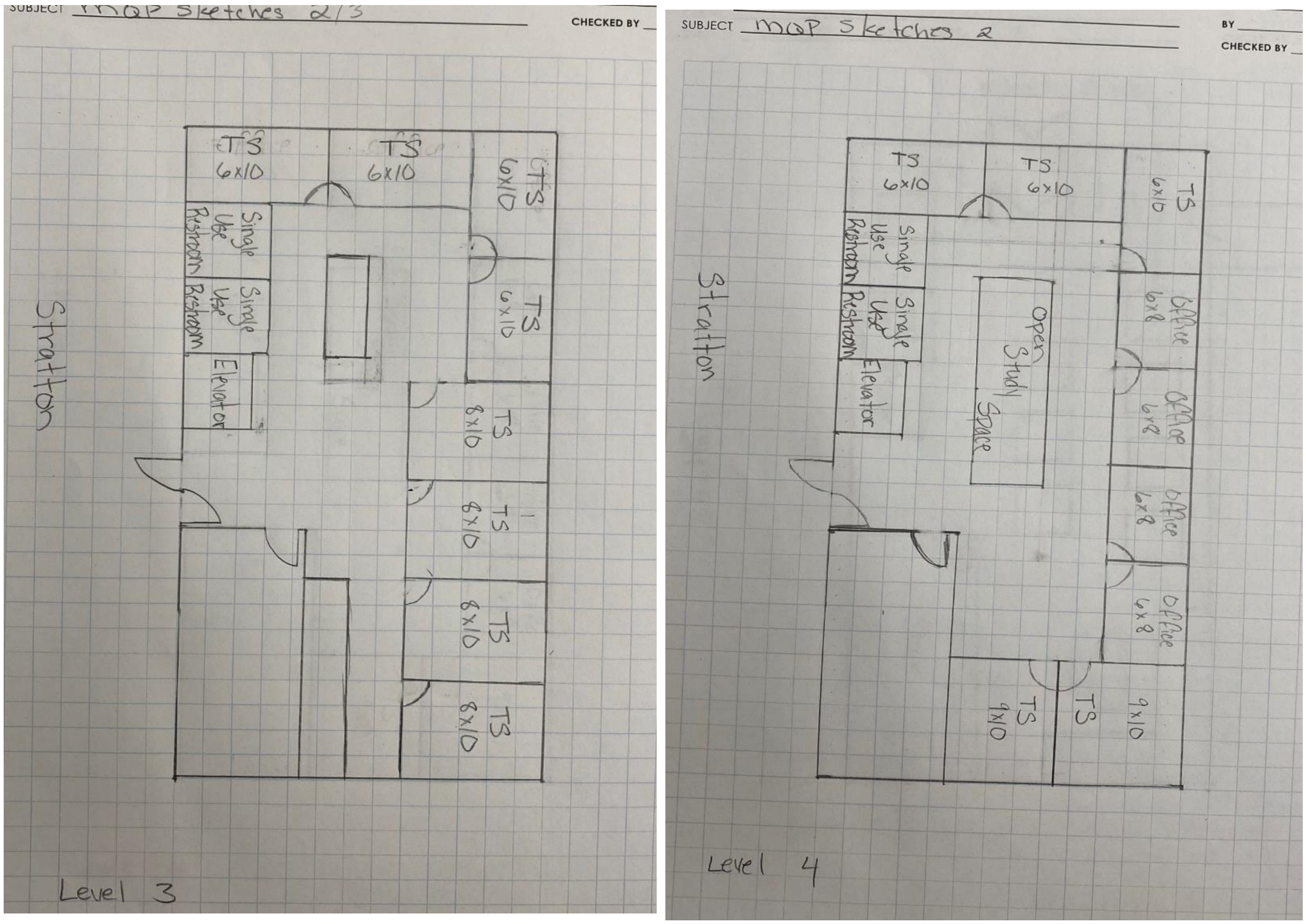
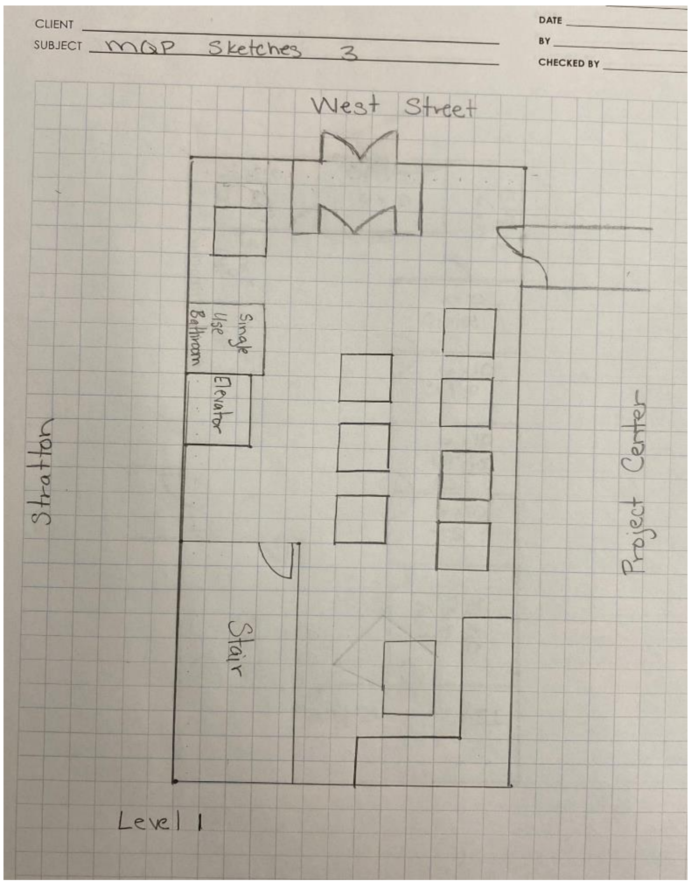


Figure 18: Second Set of Floor Layout Sketches

For the final set of sketches, a few changes were made to the floor layouts. These changes addressed the few issues discovered in the last set of sketches that had to be addressed before creating the Revit model. On the first floor, a vestibule was added to provide a buffer between the outdoor weather conditions and the controlled air and temperature conditions within the proposed addition. This way students working on the first floor are not disturbed by the inflow of cold or hot air when the door opens. The connecting hallway on the first floor leading into Stratton Hall was also eliminated. This modification was necessary because the top of floor elevation for the first floor of Stratton does not align with the first floor of both the proposed connection and the Project Center. Instead of having a small set of stairs to lead into the space, students can utilize the stairway or the elevator. The fourth floor was redesigned to increase office space and add a conference room that can be used for large student group meetings or for faculty meetings. The layouts of the second and third floors did not change from the second set of sketches.



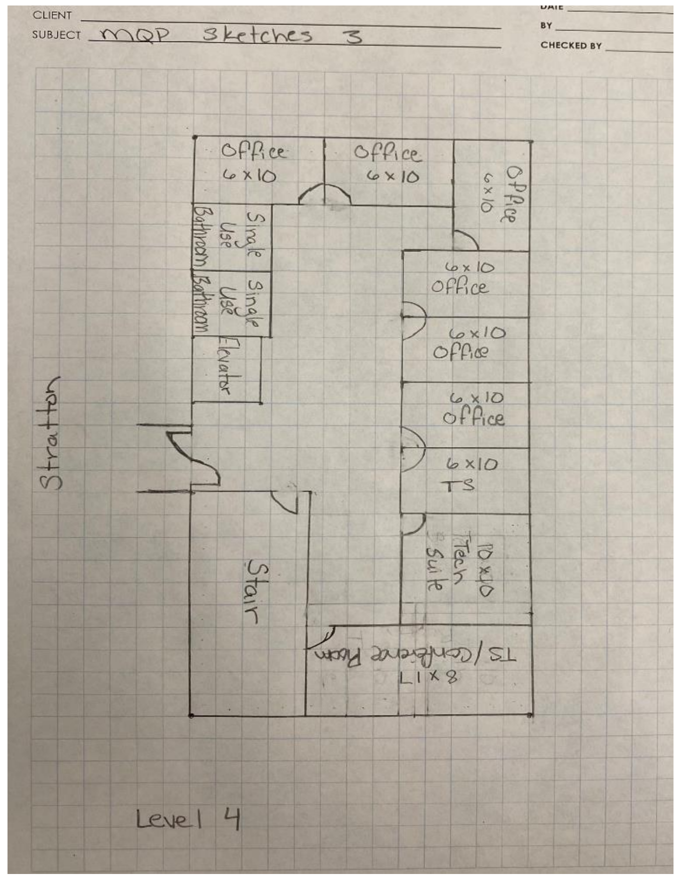


Figure 19: Third Set of Floor Layout Sketches

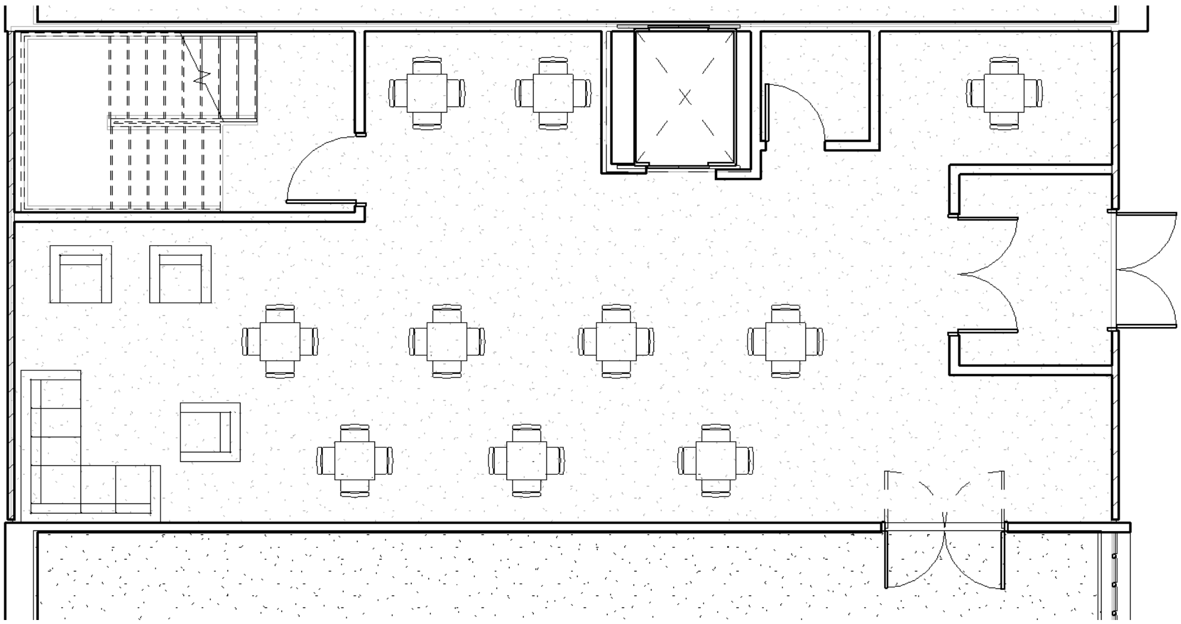


Figure 20: Level 1 Revit Floor Layout 1

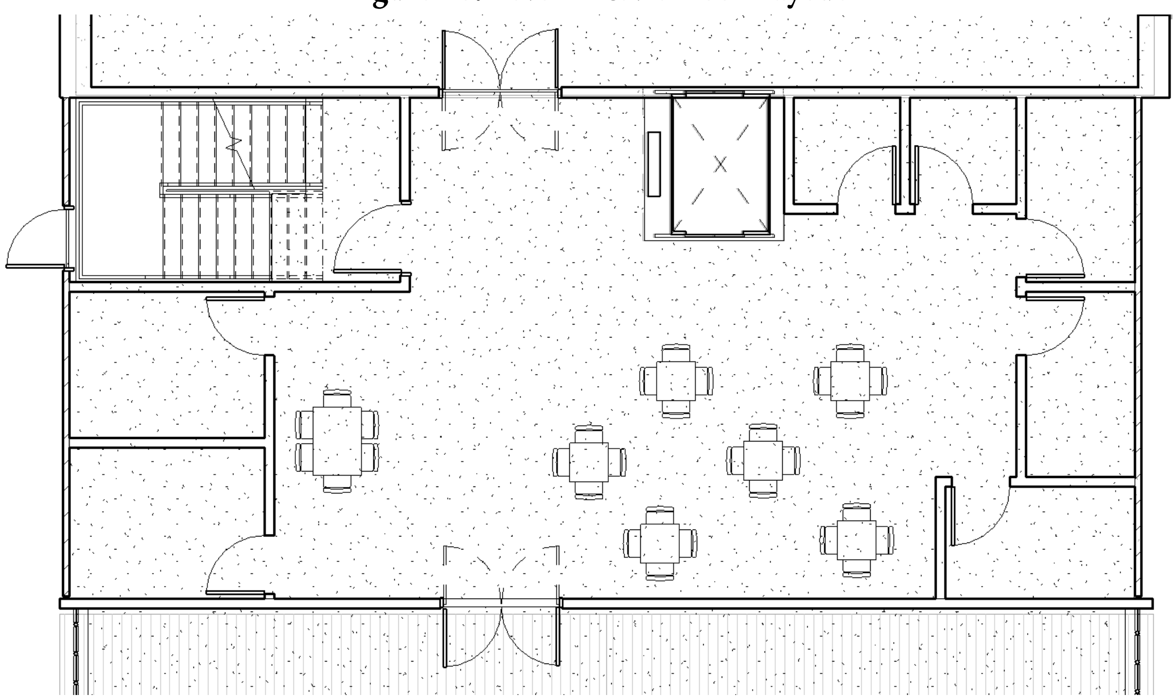


Figure 21: Level 2 Revit Floor Layout 1

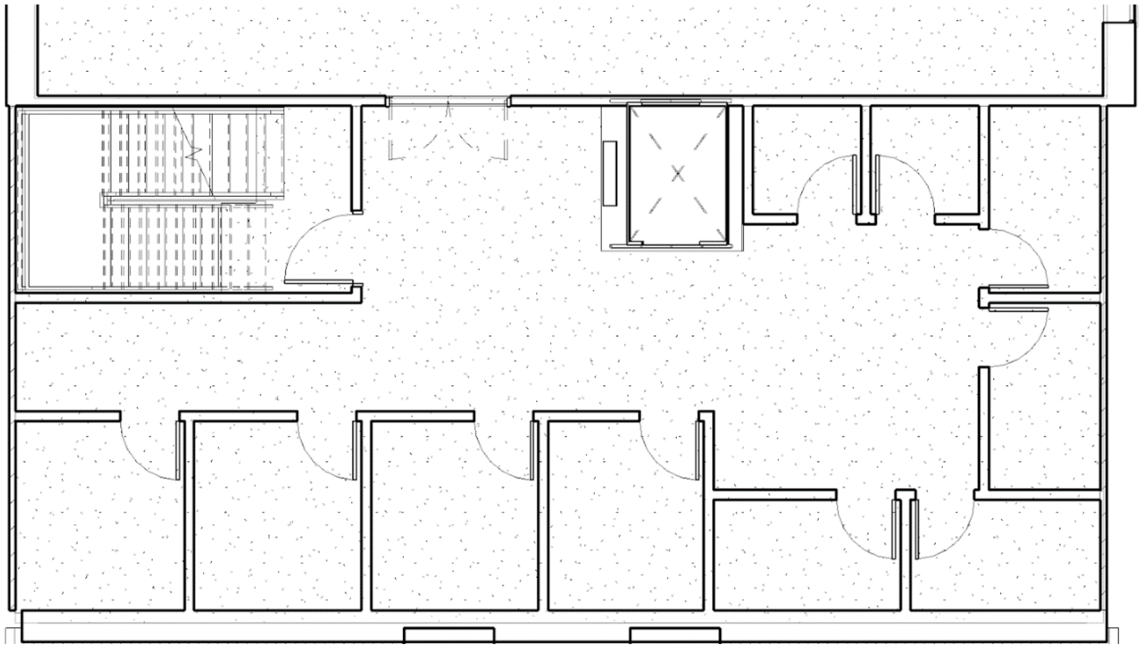


Figure 22: Level 3 Revit Floor Layout 1

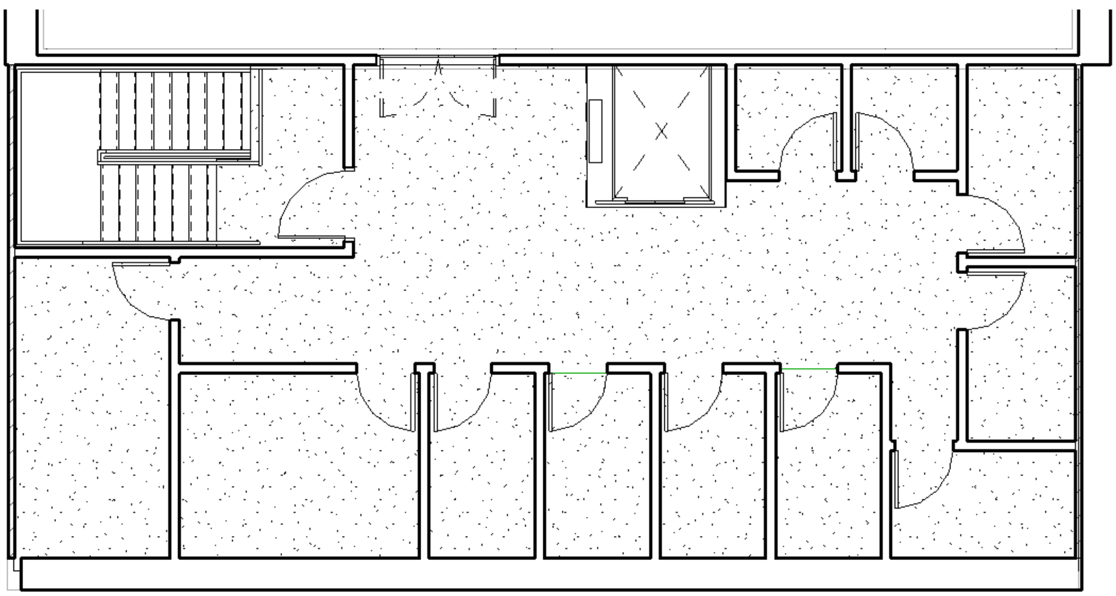


Figure 23: Level 4 Revit Floor Layout 1

In the final set of floor layouts some changes had to be made in order to ensure that the proposed building is code compliant. This included switching the location of the restrooms with the door leading into Stratton Hall and making the stairway larger. The exit leading into Stratton was originally too close to the stairwell exit, and the two were switched in order to meet the requirements of the *Massachusetts State Building Code*. This change is further discussed in Section 4.2.3 Fire Protection Systems. The other change that was made was increasing the length of the stairwell; this was necessary to make sure the stairs lined up properly with the floors. Since the length of the stairway was increased, the two gender-neutral bathrooms that were originally proposed on each floor became a single bathroom per floor. Given the occupant loads for the building and the additional restrooms located in Stratton Hall and the Project Center, the loss of the additional restroom per floor will not make a significant difference in the building.

The final layouts also include fully furnished rooms to give a better sense of size relative to the use of each room. The structural system of steel beams girders and columns was also included in the final layouts, and the columns can be seen on each floor. The placement of some columns required the repositioning furniture in some of the open study spaces. Although the furniture layout changed, the overall functionality and use of the space remains unaffected by the column placement.

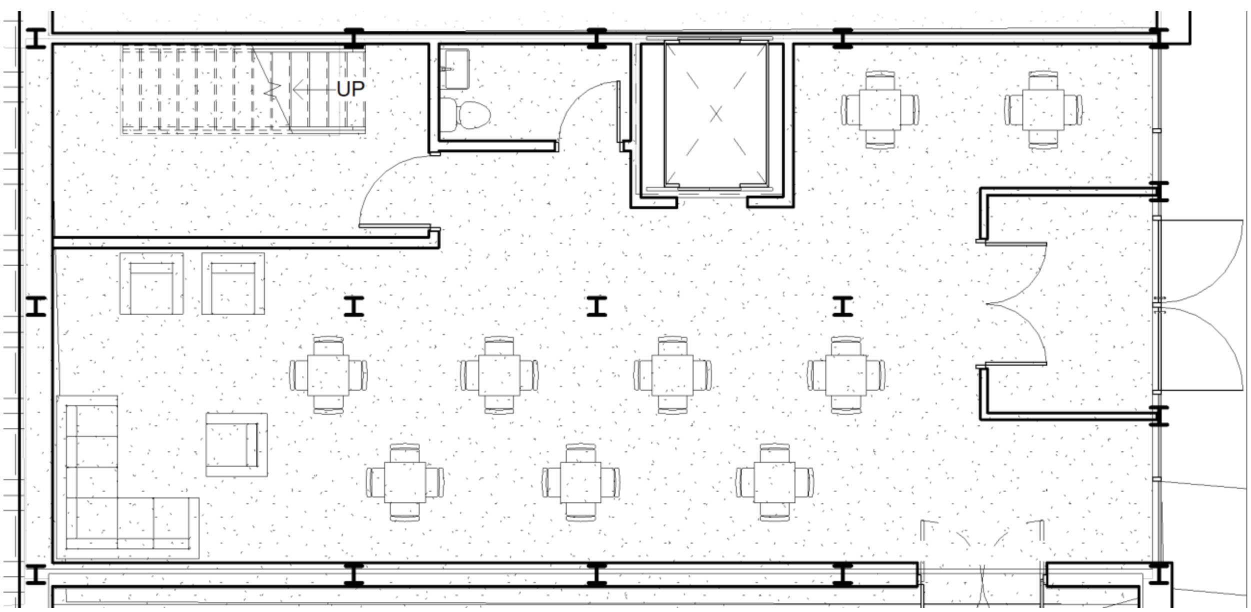


Figure 24: Final Layout Level 1

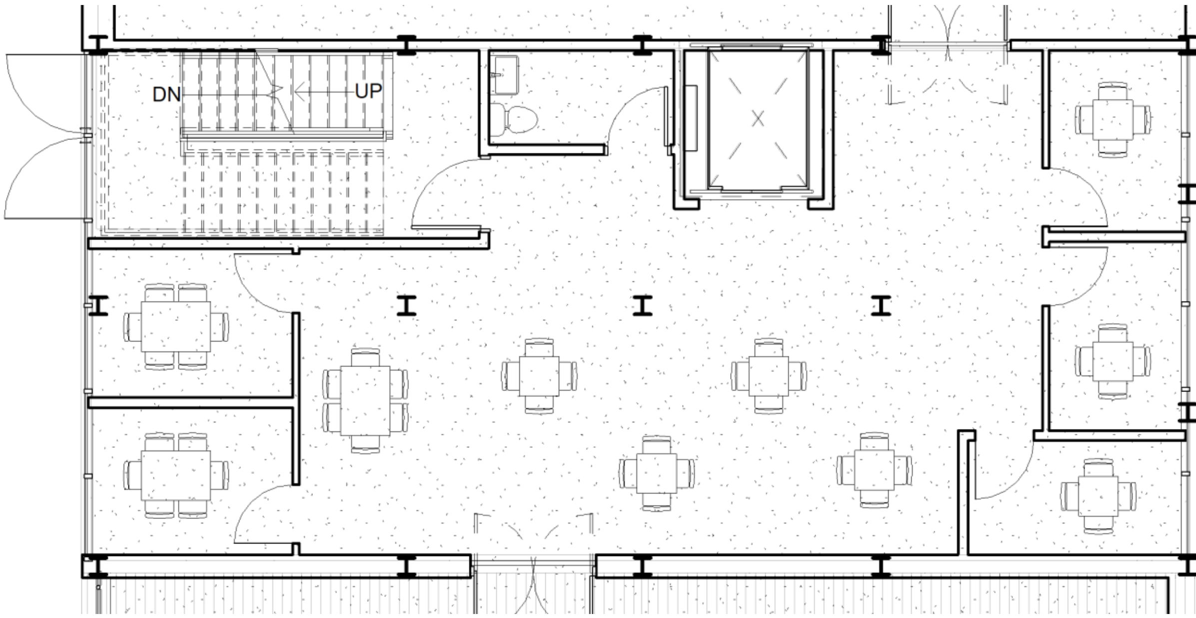


Figure 25: Final Layout Level 2

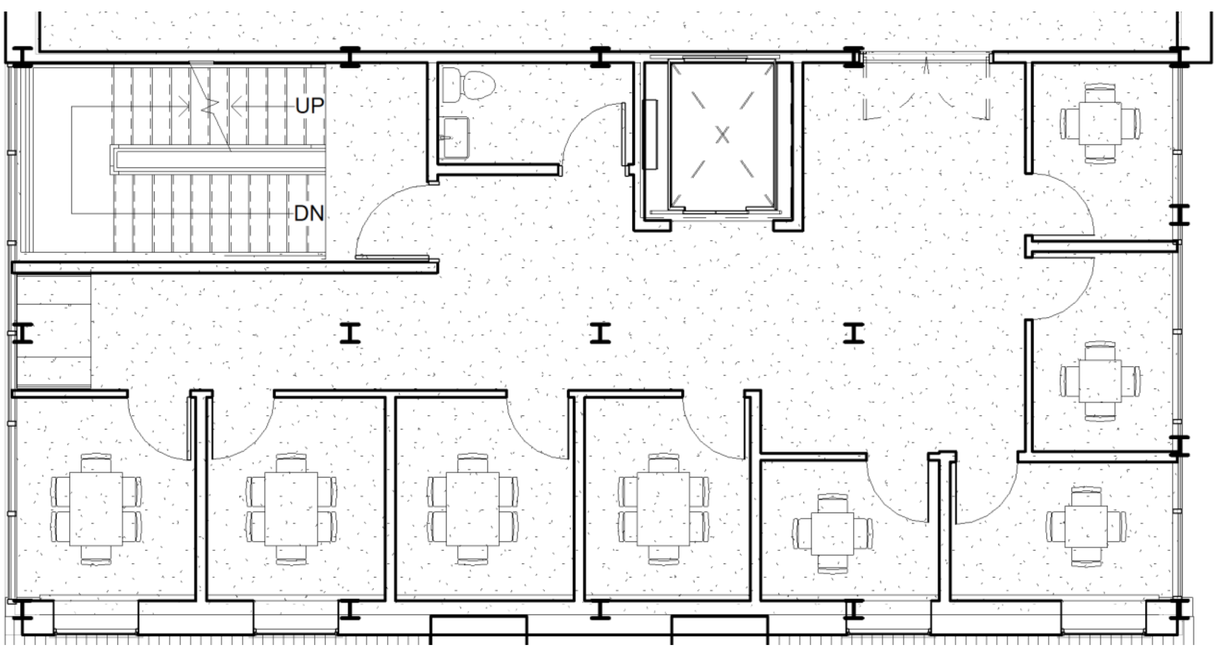


Figure 26: Final Layout Level 3

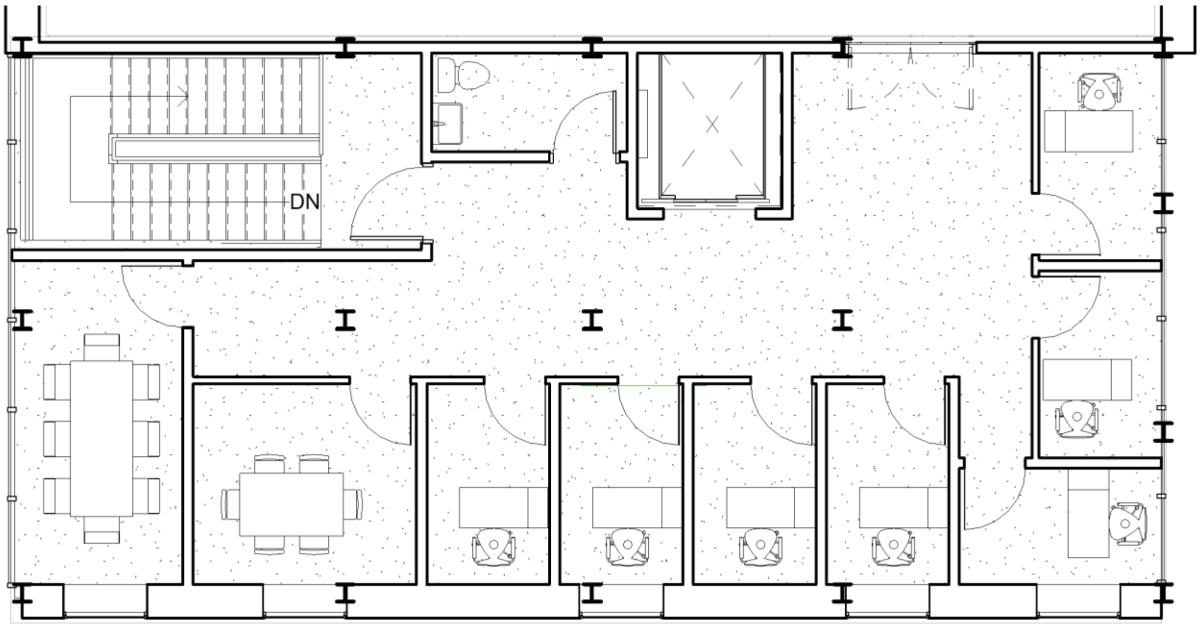


Figure 27: Final Layout Level 4

4.2.2 3D Model

A 3D model was created by incorporating the elements of the proposed new construction within the Revit model of the existing conditions. The inclusion of the surrounding environment displays the varying elevations that will be worked with during the construction process. This provides vital information for the construction process to be viewed in its final state, so that proper planning can be done to work with the surrounding environment. The model, as seen in *Figure 28*, also serves as a way to make sure the building fits in with its surroundings, such as the other buildings it is connected to.

The creation of a 3D model also allowed for a better visualization of interior spaces in the floor plans that were created. The finishes of materials were able to be viewed in detail, to ensure the space will be aesthetically and functionally appropriate for its uses. The open study spaces in the S.H.A.F.T. were looked at in a 3D view to ensure that there is sufficient area for adequate spacing of furniture relative to other furniture, columns, and walls is present. Tech suites and offices were also displayed in the 3D model to properly size desks and tables for the number of people who will be using the spaces.

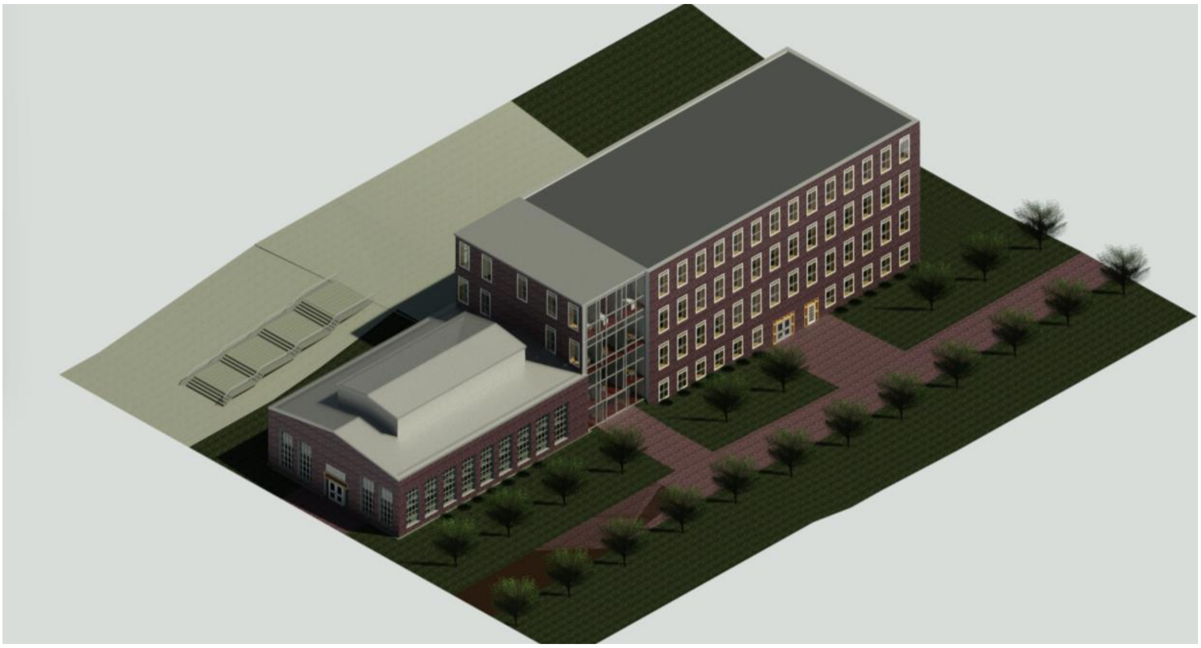


Figure 28: Southeast View

Figure 29: West Street Entrance

Figure 30: Level 1 Open Study Area

Figure 31: Interior of Typical Four Person Tech Suite

4.2.3 Fire Protection Systems

Although all of them cannot be seen in the drawings, the building was designed with fire safety systems in order to comply with current fire codes. This includes equipping the building throughout with an automatic sprinkler system in compliance with NFPA 13 requirements. Also, the walls separating the S.H.A.F.T. from Stratton Hall and the Project Center have a 2-hour fire resistance rating. Providing 2-hour rated fire barriers allow for the use of horizontal exits. These can be seen in *Figures 32-35* below; red indicates a 2-hour fire rated barrier. Horizontal exits lead to Stratton and the Project Center and provide an alternative means of egress to the staircase serving the four stories. The horizontal exit is necessary since a minimum of two exits are required per floor in accordance with Section 1006.3.1 of the *Massachusetts State Building Code* for buildings with 1 to 500 occupants per floor. These two exits are required to be a minimum of one-third of the total diagonal distance of the building because the building is sprinklered throughout (Section 1007.1.1 MBC). The total diagonal distance of the building is 58'. In the final design the doors leading into Stratton were moved in order to meet this requirement. The stairway and the horizontal exit now stand at 23' apart, meeting the building code requirement. Fire doors will be used at the horizontal exits in order to continue the fire barrier protection that the wall provides. The elevator shaft and stairwell are also provided with 2-hour fire barriers because the shafts extend four stories, and a 2-hour rating is required per Section 7.3.4 of the *Massachusetts State Building Code.*

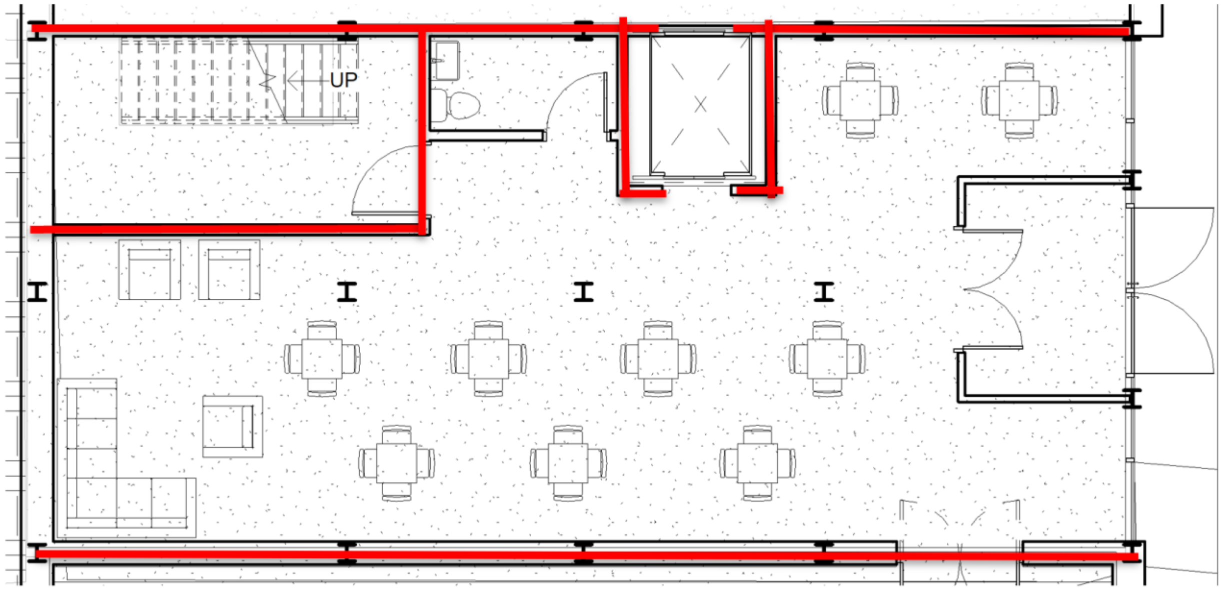


Figure 32: Fire Rated Walls Level 1

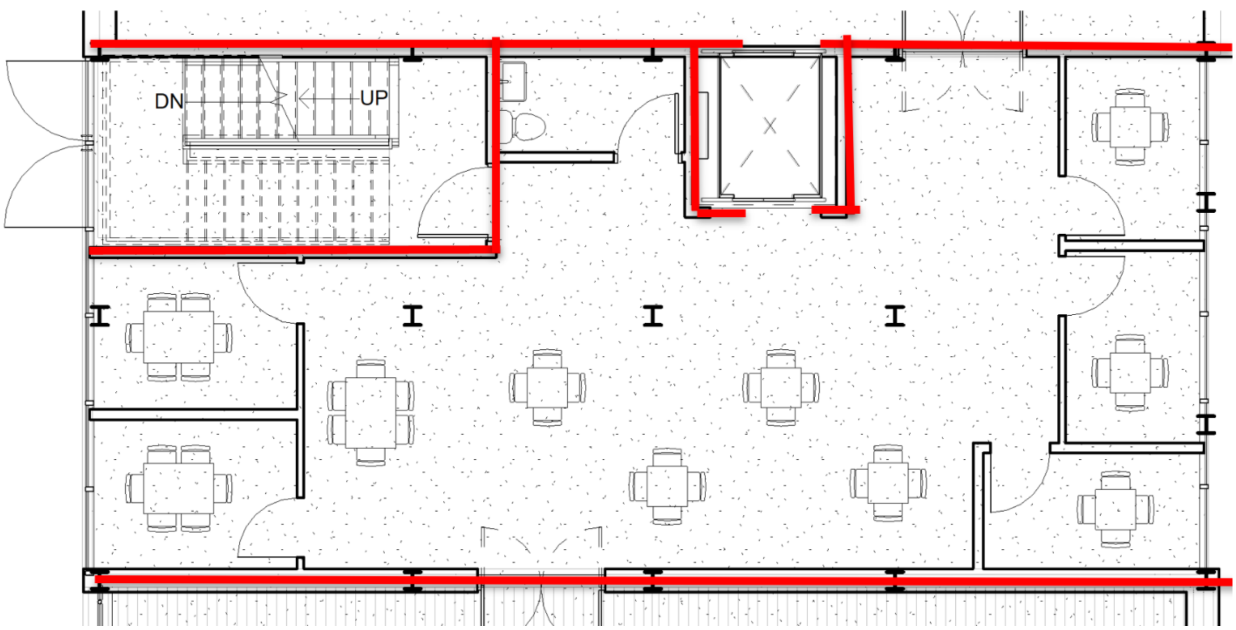


Figure 33: Fire Rated Walls Level 2

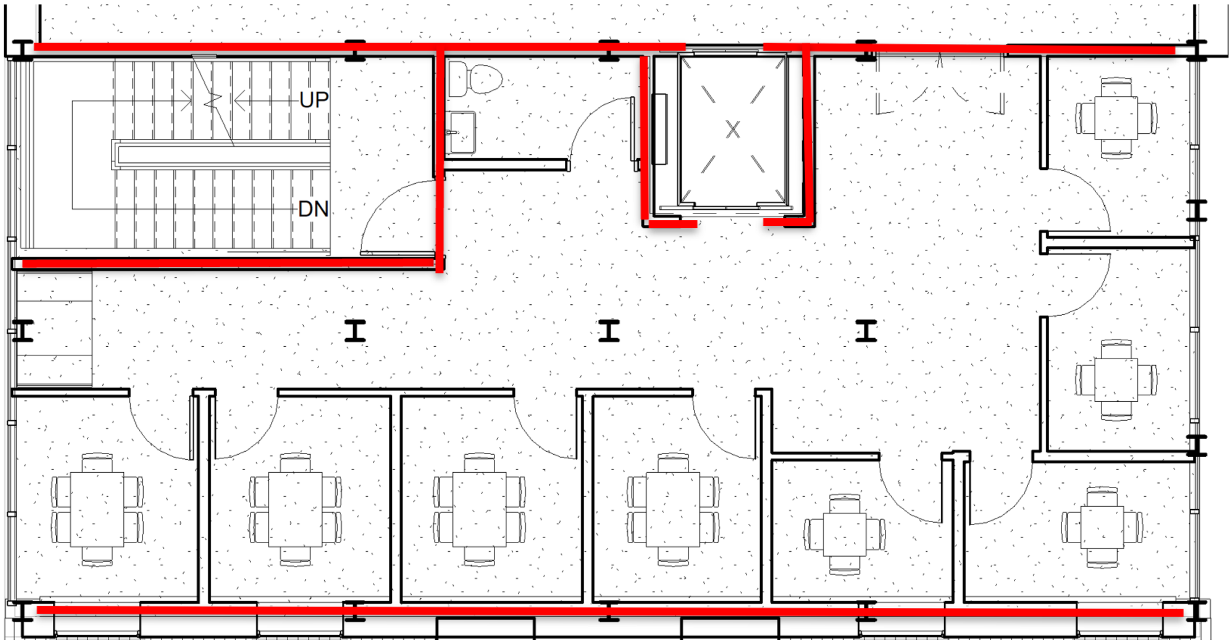


Figure 34: Fire Rate Walls Level 3

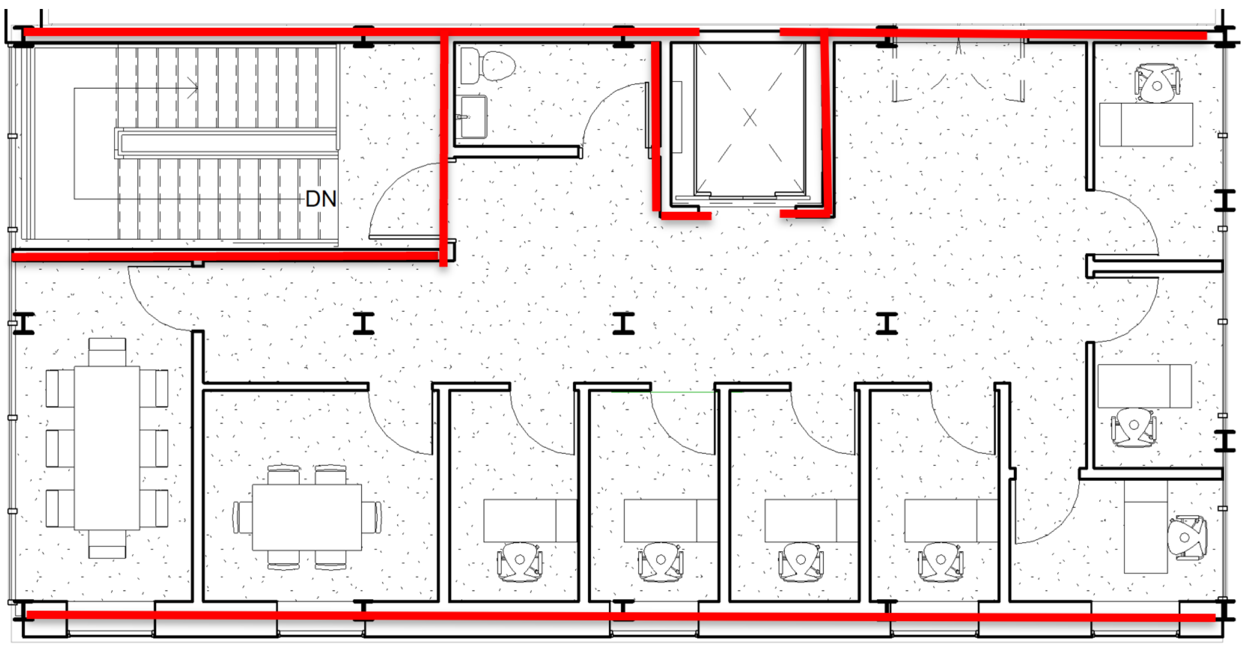


Figure 35: Fire Rated Walls Level 4

4.2.4 Egress Analysis

Along with fire protection systems that were included in the building, an egress analysis was performed to ensure that all occupants can safely exit the building in case of an emergency. The supporting calculations, which are summarized in *Tables 5 through 8,* demonstrate that the current egress capacity is more than sufficient to service the building's current occupant load. In the future, if occupancy loads were to change, an increased occupant loading can be accommodated without the need to resize the stairway or add additional exits.

Table 5: Level 1 Egress Analysis

Level 1

Room	Occupancy Type	Occupant Load (	Area	Occupants
Open Study Area	Assembly-unconcentrated	15	980	66
Lounge Area	Assembly-unconcentrated	15	295	20
Total				86

EXIT/EXIT ACCESS COMPONENT	STAIR WIDTH (IN)	STAIR FACTOR (IN/OCC)	STAIR CAPACITY (OCC)	REQ STAIR WIDTH (IN)	DOOR WIDTH (IN)	DOOR WIDTH FACTOR (IN/OCC)	DOOR CAPACITY (OCC)	REQ DOOR WIDTH (IN)	GOVERNING CAPACITY	ACTUAL USE
Stair 01	48	0.2	240	44	42	0.15	280	32	240	20
Exit 01					72	0.15	480	32	480	33
Exit 02					72	0.15	480	32	480	33
	TOTAL			TOTAL	TOTAL			TOTAL	TOTAL	TOTAL
	48			44	186			96	1,200	86

Table 6: Level 2 Egress Analysis

Level 2

Room	Occupancy Type	Occupant Load Factor	Area	Occupants
Open Study Area	Assembly- unconcentrated	15	800	54
Tech Suite	Assembly- unconcentrated	15	66.5	5
Tech Suite	Assembly- unconcentrated	15	66.5	5
Tech Suite	Assembly- unconcentrated	15	71.3	5
Tech Suite	Assembly- unconcentrated	15	80	6
Tech Suite	Assembly- unconcentrated	15	80	6
Total				81

EXIT/EXIT ACCESS COMPONENT	STAIR WIDTH (IN)	STAIR FACTOR (IN/OCC)	STAIR CAPACITY (OCC)	REQ STAIR WIDTH (IN)	DOOR WIDTH (IN)	DOOR WIDTH FACTOR (IN/OCC)	DOOR CAPACITY (OCC)	REQ DOOR WIDTH (IN)	GOVERNING CAPACITY	ACTUAL USE
Stair 01	48	0.2	240	44	42	0.15	280	32	240	27
Exit 01					72	0.15	480	32	480	27
Exit 02					72	0.15	480	32	480	27
	TOTAL			TOTAL	TOTAL			TOTAL	TOTAL	TOTAL
	48			44	186			96	1,200	81

Table 7: Level 3 Egress Analysis

Level 3

Room	Occupancy Type	Occupant Load (	Area	Occupants
Tech Suite	Assembly-unconcentrated	15	87.5	6
Tech Suite	Assembly-unconcentrated	15	87.5	6
Tech Suite	Assembly-unconcentrated	15	87.5	6
Tech Suite	Assembly-unconcentrated	15	87.5	6
Tech Suite	Assembly-unconcentrated	15	69.5	5
Tech Suite	Assembly-unconcentrated	15	69.5	5
Tech Suite	Assembly-unconcentrated	15	73.5	5
Tech Suite	Assembly-unconcentrated	15	60	4
Total				43

EXIT/EXIT ACCESS COMPONENT	STAIR WIDTH (IN)	STAIR FACTOR (IN/OCC)	STAIR CAPACITY (OCC)	REQ STAIR WIDTH (IN)	DOOR WIDTH (IN)	DOOR WIDTH FACTOR (IN/OCC)	DOOR CAPACITY (OCC)	REQ DOOR WIDTH (IN)	GOVERNING CAPACITY	ACTUAL USE
Stair 01	48	0.2	240	44	42	0.15	280	32	240	22
Exit 01					72	0.15	480	32	480	21
	TOTAL			TOTAL	TOTAL			TOTAL	TOTAL	TOTAL
	48			44	114			64	720	43

Table 8: Level 4 Egress Analysis

Level 4

Room	Occupancy Type	Occupant Load (	Area	Occupants
Office	Business- B	150	62.5	1
Office	Business- B	150	62.5	1
Office	Business- B	150	62.5	1
Office	Business- B	150	62.5	1
Office	Business- B	150	66	1
Office	Business- B	150	66	1
Office	Business- B	150	62	1
Tech Suite	Assembly-unconcentrated	15	110	8
Conference Room	Assembly-unconcentrated	15	136	10
Total				25

EXIT/EXIT ACCESS COMPONENT	STAIR WIDTH (IN)	STAIR FACTOR (IN/OCC)	STAIR CAPACITY (OCC)	REQ STAIR WIDTH (IN)	DOOR WIDTH (IN)	DOOR WIDTH FACTOR (IN/OCC)	DOOR CAPACITY (OCC)	REQ DOOR WIDTH (IN)	GOVERNING CAPACITY	ACTUAL USE
Stair 01	48	0.2	240	44	42	0.15	280	32	240	13
Exit 01					72	0.15	480	32	480	12
	TOTAL			TOTAL	TOTAL			TOTAL	TOTAL	TOTAL
	48			44	114			64	720	25

4.2.5 Mechanical Systems

As shown above in the floor designs, the elevator was placed on the Stratton Hall side of the building extension. The elevator was selected to fit the specific needs for the space. It must service all floors with doors on each side of the car to service both Stratton Hall traffic as well as any traffic coming from the proposed addition, take up minimal space, and not be piston driven. The elevator is intended to reach the first floor of Stratton Hall where the current Math Tutoring Center is located as well as all four floors of the addition. The elevator must also be compact due to the limited space in the addition. The selected elevator system is a Schumacher MRL traction elevator: it is electric, has a capacity of 2500 lbs, is double-sided, and will require an elevator shaft dimension of 9'9" x 6'6 1/2" to properly fit the interior cab that has dimensions of 6'8" x4'3." The selected elevator's specification and design sheet are located in Appendix B. The advantages of this type of elevator are that it does not require a machine room, is more efficient than its hydraulic counterparts, and is code compliant – please insert rationale or reference for this information (*Schumacher, MRL elevators*).

As previously mentioned, the interior of the proposed addition will be climate controlled. This requires HVAC units to be housed in close proximity to the addition. It was decided that an additional, smaller mechanical penthouse shall be placed on the roof of the new addition for some units while the others will be located in a more expansive mechanical penthouse that is currently located on top of the Project Center. The gas service units will be moved and housed in front of the Project Center and Stratton Hall, the West Street side, respectively while the additional gas service unit for the new renovation will be housed facing the Power House and Washburn Shops.

4.2.6 Structural Systems

Structural steel framing was selected to support the building. Even though it will be attached to Stratton Hall and the Project Center on either side, the structural system for this structure will function independently of the other buildings. Due to the varying layouts per floor, the columns shall be placed based on the floor layout and will not be uniform throughout all four floors. Placement of columns is strategic to utilize the open space; this is done by hiding columns in the walls of the tech suites and offices on the upper floors.

4.2.6.1 Structural Analysis

Multiple steps were taken to complete a full design and analysis of the structural grid. Calculations were made to determine beam, girder, and column sizes. *Table 9*, shows the load analysis used to determine column sizes. The dead load, live load and snow loads were applied to each structural column based on the tributary area of the column. The results from the calculations showed the forces acting on each member and using that information, the required HSS member was determined to be 9"x9"x1/4". The design of the structural grid was first determined using the Revit model. The modeling software helped precisely place column locations and a front view of the structural grid can be seen below in *Figure 36*.

The beam and girder layout, which can be seen in *Figure 37*, was spaced out six feet apart to adequately support the entirety of the floor. Data from Tables 3-19, 3-20, and 3-21 in the *AISC Manual of Steel Construction* were used to determine design strengths for different sized members. From there, data taken from the spreadsheet shown in *Table 10* was used to calculate the design loads for each girder and beam. The calculations of the beam and girder sizes can be found in Appendix D. The resulting member sizes that came from the analysis wW21x44 sizing for beams and W33x141 for the girders. In total there were 32 total columns, each approximately 25 feet tall. Additionally, the structure has 12 girders, all of which are roughly 27.5 feet in length. Between the girders, 11 beams were placed on each support the concrete slab on metal decking. With three total grids, this totaled up to 33 beams in all. Finally, it was determined that 6 studs would be necessary for beam connections, and 8 for girder connections according to AISC Table 3-21.

Table 9: Column Analysis Spreadsheet

Column	Column Height	SF	Column	MEP	Floor Slab	Total Dead Load
1	25	51.344	730.75	256.72	2823.92	3811.39
2	25	91.094	730.75	455.47	5010.17	6196.39
3	25	79.5	730.75	397.5	4372.5	5500.75
4	25	91.094	730.75	455.47	5010.17	6196.39
5	25	30.031	730.75	150.155	1651.705	2532.61
6	25	72.656	730.75	363.28	3996.08	5090.11
7	25	102.688	730.75	513.44	5647.84	6892.03
8	25	182.188	730.75	910.94	10020.34	11662.03
9	25	159	730.75	795	8745	10270.75
10	25	182.188	730.75	910.94	10020.34	11662.03
11	25	72.656	730.75	363.28	3996.08	5090.11
12	25	51.344	730.75	256.72	2823.92	3811.39
13	25	91.094	730.75	455.47	5010.17	6196.39
14	25	79.5	730.75	397.5	4372.5	5500.75
15	25	91.094	730.75	455.47	5010.17	6196.39
16	25	30.031	730.75	150.155	1651.705	2532.61
						99142.12

		Loading (psf)
	Beams	10
	Floor Slab	55
HSS 9"x9"x1/4"	Columns	29.23
	MEP	5
	Snow	55

Floor 2	297426.36
Floor 3	198284.24
Floor 4	99142.12

Total LRFD	Snow Load	Total Loading (Kips) 1.2DL+1.6LL+0.5SL
1	2823.92	50.21529104
2	5010.17	81.9537374
3	4372.5	52.77771
4	5010.17	68.83612884
5	1651.705	23.25539066
6	3996.08	52.52938896
7	5647.84	83.01257008
8	10020.34	145.4867657
9	8745	130.27272
10	10020.34	151.8025913
11	3996.08	52.52938896
12	2823.92	37.89273104
13	5010.17	68.10722964
14	4372.5	61.04571
15	5010.17	67.37849348
16	1651.705	23.25539066

4th Floor

Column	SF	Office	Bathroom	Stairs	Corridor	Assembly	Mechanical	Floor	Roof	Total Live Load
1	51.344	0	0	51.344	0	0	0	5134.4	2174.418	7308.8184
2	91.095	0	30.365	30.365	30.365	0	0	7743.075	3857.873	11600.948
3	79.5	0	39.75	0	0	0	39.75	2981.25	3366.825	6348.075
4	91.094	0	0	0	45.547	0	45.547	3643.76	3857.831	7501.5909
5	30.031	30.031	0	0	0	0	0	1501.55	1271.813	2773.3629
6	72.656	72.656	0	0	0	0	0	3632.8	3076.982	6709.7816
7	102.688	68.459	0	34.229	0	0	0	6845.85	4348.837	11194.687
8	182.188	45.547	0	0	136.641	0	0	13208.63	7715.662	20924.292
9	159	0	0	0	159	0	0	12720	6733.65	19453.65
10	182.188	0	0	0	182.188	0	0	14575.04	7715.662	22290.702
11	72.656	72.656	0	0	0	0	0	3632.8	3076.982	6709.7816
12	51.344	51.344	0	0	0	0	0	2567.2	2174.418	4741.6184
13	91.094	30.365	0	0	60.729	0	0	6376.57	3857.831	10234.401
14	79.5	0	0	0	79.5	0	0	6360	3366.825	9726.825
15	91.094	45.547	0	0	45.547	0	0	5921.11	3857.831	9778.9409
16	30.031	30.031	0	0	0	0	0	1501.55	1271.813	2773.3629
										160070.84

	Loading (psf)
Office	50
Bathroom	75
Stairs	100
Corridor	80
Assembly	100

3rd Floor Live	2nd Floor Live
7308.818	7308.818
12056.291	12056.291
6348.075	6546.825
9323.553	10689.881
2773.363	2773.363
6709.782	6709.782
12221.465	11194.687
21076.131	19557.882
17863.65	18261.15
22290.702	20924.292
6709.782	6709.782
4741.618	4741.618
8412.531	8412.531
7341.825	7341.825
8412.531	8412.5309
2773.363	2773.363

Sample calculations used to create the column analysis spreadsheet can be seen below in Appendix F. Tributary areas were calculated using the column positions, and using the weights of the building materials being used, live loads and dead loads were able to be determined for each column.

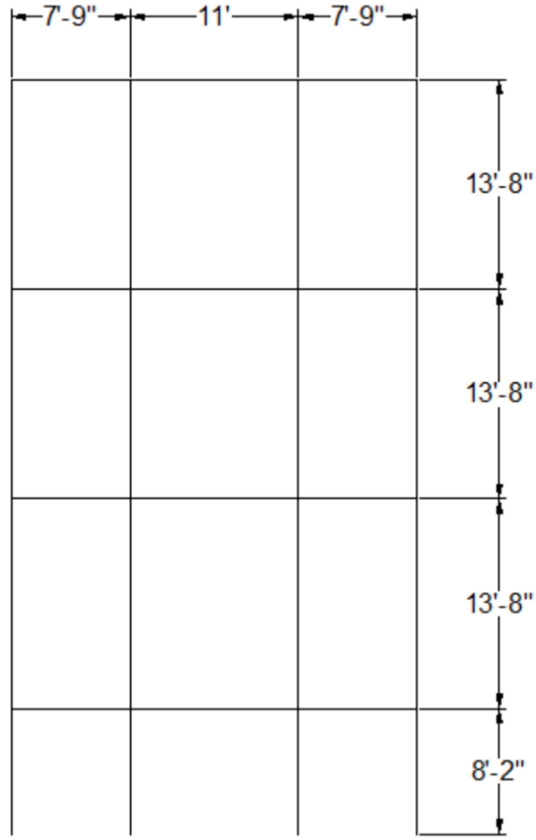


Figure 36: Eastern View of Structural Support Columns with story heights

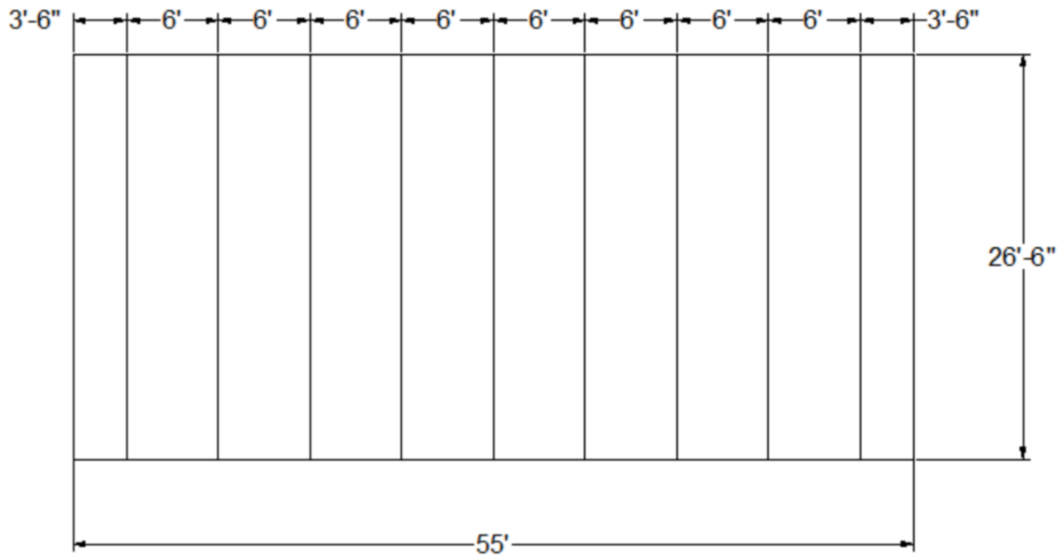


Figure 37: Beam and Girder Layout

4.2.7 Cost Estimate

To estimate the proposed design two different approaches were taken. The first approach was based on quantity takeoff; the second approach involved a cost per square foot. The quantity takeoff approach is more comprehensive and used typically in design development drawings, it provides a more accurate and precise estimate compared to the second approach. The limitation of quantity takeoff is that it can only be used if drawings and sufficient design information are available; otherwise, the cost-per-square-foot method is used to provide a reasonable estimate.

In the case of the connection between Stratton Hall and the Project Center, a limited set of architectural and structural drawings have been produced. The scope of work did not further explore the design of the HVAC systems and the required use of reinforced concrete construction. These factors, in combination with a lack of construction specifications, led to more reliance on the cost-per-square-foot approach which used previous estimate information from similar academic buildings. This enabled the creation of a cost estimate for the new construction and the associated renovations to Stratton Hall and the Project Center.

Cost-per-square-foot values were obtained for CSI divisions, 1, 2, 21, 22, 23, and 26. The rest of 14 divisions had enough detail to accurately estimate quantities, such as masonry, metals, rough and finish carpentry, thermal and moisture protection, openings, finishes, specialties, appliances, conveying equipment, hardscaping, exterior improvements, and site work. These quantities were gathered from using OST (On-Screen Takeoff), software used during previous internships, and then in combination with Sage Estimating software and Excel, the work was priced. *Table 10* displays the cost of each division, a more detailed version can be found in Appendix C.

Table 10: Cost Estimate per each Construction CSI Division

	Project Name: WPI's "SHAFT"	Building GSF	6,040
		No. of Floors:	4
DIVISION #	**DESCRIPTION**	**DIVISION COST**	**COST/ SF**
Division 1	General Requirements	$ 86,000	$ 14.20
Division 2	Existing Conditions	$ 74,110	$ 12.30
Division 3	Concrete	$ 192,700	$ 31.90
Division 4	Masonry	$ 74,688	$ 12.40
Division 5	Metals	$ 359,816	$ 59.60
Division 6	Wood, Plastics & Composites	$ 65,183	$ 10.80
Division 7	Thermal & Moisture Protection	$ 202,515	$ 33.59
Division 8	Openings	$ 620,925	$ 102.80
Division 9	Finishes	$ 661,914	$ 109.60
Division 10	Specialties	$ 4,320	$ 0.76
Division 11	Equipment	$ 5,000	$ 0.80
Division 12	Furnishing	$ 79,700	$ 13.20
Division 14	Conveying Equipment	$ 335,000	$ 55.50
Division 21	Fire Protection	$ 33,500	$ 5.55
Division 22	Plumbing	$ 78,740	$ 13.09
Division 23	HVAC/ Mechanical	$ 366,900	$ 60.79

Division 26	Electrical	$ 223,480	$ 37.06
Division 31	Earthwork	$ 53,559	$ 8.98
Division 32	Exterior Improvements	$ 21,423	$ 3.55
Division 33	Utilities	$ 28,516	$ 4.76
TOTAL COST		**$ 3,532,789**	**$ 584.90**
OVERHEADS & PROFIT	**35%**	**$ 1,236,476**	
TOTAL BASE BID		**$ 4,769,265**	

Although quantity takeoff was possible, to determine prices we used prior experiences and knowledge gained from internships with Consigli Construction and Simpson Gumpertz & Heger (SGH) as well as resources made available by previous colleagues. The total price of material and labor is different than what it would cost WPI if they had a General Contractor build it for them, which is shown through the 35% adjustment incorporated into the "Base Bid" in *Table 9*. The one setback is that without having a specification to describe in details the materials and systems to be used, assumption had to be made to prepare the cost estimate. The assumptions and qualifications of the cost estimate are outlined below.

Assumptions and Qualifications

Division 1 – General Requirements

Division 1 there were no additional assumptions to be made. General requirements were carried that are standard for estimates prepared by Consigli Construction, such as exterior wall mockups, final cleanup, window and glass cleaning, etc.

Division 2 – Existing Conditions

A significant portion of the proposed project is a renovation that requires the demolition and removal of certain structures and systems from existing buildings, such as the demolition of existing brick CMU walls and the relocation of existing gas service pipelines. This demolition requires structural reassurance while undergoing construction which is accounted for in the estimate.

Division 3 – Concrete

Concrete is one of the main concerns associated with any structure. A general slab on grade with welded wire reinforcement was used in preparing our estimate. In addition, columns were secured with footings and tied into each floor's metal deck. Above the slab on grade, each floor was finished with 3" concrete on top of metal deck.

Division 4 – Masonry

Brick masonry walls were used for the exterior facade that was not a curtain wall. It was also used for the interior walls separating the connection from the Project Center and Stratton Hall. Loose lintels and grouting were also included for the double doors located on a masonry wall.

Division 5 – Metals

A total tonnage was calculated from the structural grid that was created using the various beam sizes and weights per linear foot. This tonnage was assigned a value of $6500 which includes roof decking. Pricing was obtained through a recent project that required 3800 tons of steel at roughly $5200 per ton. The price was ultimately escalated for our project d to the significantly less steel that is included in comparison. Metal decking for flooring was included as a breakout cost from the total structural steel value. An allowance of 5% of the total structural steel value is also carried for miscellaneous metal connections used for the structure.

Division 6 – Wood, Plastic & Composites

Typical rough carpentry (framing and blocking) was assumed and carried out through all general partition walls, 2-hr fire-rated walls, as well as for roofing (roof blocking). In addition, basic millwork was included in this division which included but not limited to built-in benches and tables.

Division 7 – Thermal Moisture Protection

Rigid insulation was included around the slab as well as exterior walls. Acoustically rated insulation was included in general partition walls in order to improve sound dampening and sound pollution from neighboring rooms. This is ultimately due to the desire to promote productivity and limit distractions. Likewise, caulking at dissimilar surfaces was included in addition to sealing at windows and openings in order to improve general building efficiency. Finally, EPDM roofing was included as it was discovered that it was used for Stratton Hall.

Division 8 – Openings

The biggest cost in this division is the curtain wall as well as the storefront system included on the first floor of the building. The curtain wall is included as a square foot price. Typically, they are priced around $150 per square foot, however, due to the small scope of the proposed project, the price was escalated slightly. The general curtain wall line item includes glass, glazing, mullions, and installation. This is similar to the storefront system that is included on the first floor of the building. General hollow metal doors were included in areas where frameless glass doors were not specified.

Division 9 – Finishes

Estimates for Division 9 were easily determined from the level of drawings created within this project. 2-hr fire-rated walls were determined to be at locations surrounding shafts as well as distinguishing the stairwell. General partitions were included at every wall where a brick CMU wall, glass partitions, or a 2-hr fire-rated wall was not specified. Stainless steel entry flooring was included at the entry vestibule on the first floor. Carpet tile was carried throughout except in areas such as the bathroom (tile was carried) or the stairway (rubber resilient flooring was carried at all treads, risers, and landings). Gypsum ceilings were carried throughout the entirety of the connection. Finally, painting of walls was the only type of wall finished included outside of the tiled walls located in the bathroom. All other finishes such as wall coverings were assumed to be discussed and done by WPI and therefore are not within the scope of the project.

Division 10 – Specialties

General bathroom fit out, furnish and installation, was included in the cost estimate and includes but not limited to grab bars, soap dispensers, coat hangers, etc.

Division 11 – Equipment

Furnishing and installation of a vending machine on the first floor of the building was included.

Division 12 – Furnishings

Furnishings such as tables, chairs, vanities, desks, and markerboards were included at all locations where specified in the drawings.

Division 14 – Conveying Equipment

As previously mentioned, a Schumacher MRL traction elevator was included and priced per flight it serviced. The flights were determined to be 5 because it will serve the bottom floor of Stratton Hall plus the proposed 4-story connection. Premiums for elevator finishes were included in the pricing for the elevator.

Division 21 – Fire Protection

Fire Protection was priced at a general cost per square foot based on previous estimates worked on. The general cost includes fire stopping and a sprinkler system throughout the entire building as mentioned in previous sections.

Division 22 - Plumbing

Plumbing was priced as well as a square foot estimate. Cost data was gathered from past colleagues, and this included $5,000 per fixture, $3.00 per square foot for storm drainage, $1.50 per square foot for gas distribution, and $1.50 per square foot for hot water equipment.

Division 23 - HVAC

Like plumbing and fire protection, HVAC was priced per square foot. The system to be included was a variable air volume (VAV) which was priced at $60 per gross square footage. The system will serve only the connection as it is compartmentalized.

Division 26 – Electrical

Electrical was determined on a cost per square foot basis. It was assumed that the building will need a security system and telephone/data system, and both cost items were carried separate to the general cost of electrical.

Division 31 – Earthwork

Earthwork or hardscaping was very general. Excavation was included in the cost and was determined by multiplying the building footprint by the needed depth. Soil testing was also included to account for the removal and disposal of possible polluted soils.

Division 32 – Exterior Improvements

Trees and a walkway were included on the basis of the 3D model of the proposed building. There is room for more plantings, and these can be further looked at.

Division 33 – Utilities

A utilities plan of the proposed construction area was not available. Consequently, 20-foot trenches for each necessary utility (water, electric, gas, etc.) were carried and assumed. In addition, materials such as HDPE for stormwater piping and PVC for freshwater piping (see appendix C for more details about selections) were determined and gathered from previous estimates.

4.2.8 Construction Timeline

The Student Help and Faculty Tower project is in the academic category. WPI has a bustling campus for about 3/4ths of the year and only a few months in the summer for construction without major inconveniences and roadblocks. Larger projects, such as Unity Hall, have been involved considerable construction activities during the active school year. To support the viability of the S.H.A.F.T., it is proposed that the majority of construction could occur during the summer months. If the project is broken into three sections: Demolition, Construction, and Finishes (including punch-list and closeout), then the relocation of impacted spaces in Stratton Hall and the Project Center may limited to total of two academic terms: D-Term when demolition occurs, and the following A-term when the project is in its final stage of finishes. In *Figure 38*, this estimate is roughly visualized.

Figure 39 is a general activity list for the proposed project. Using estimated durations from the construction of Bartlett Hall, we considered what a smaller scale could be in terms of achieving those three milestones

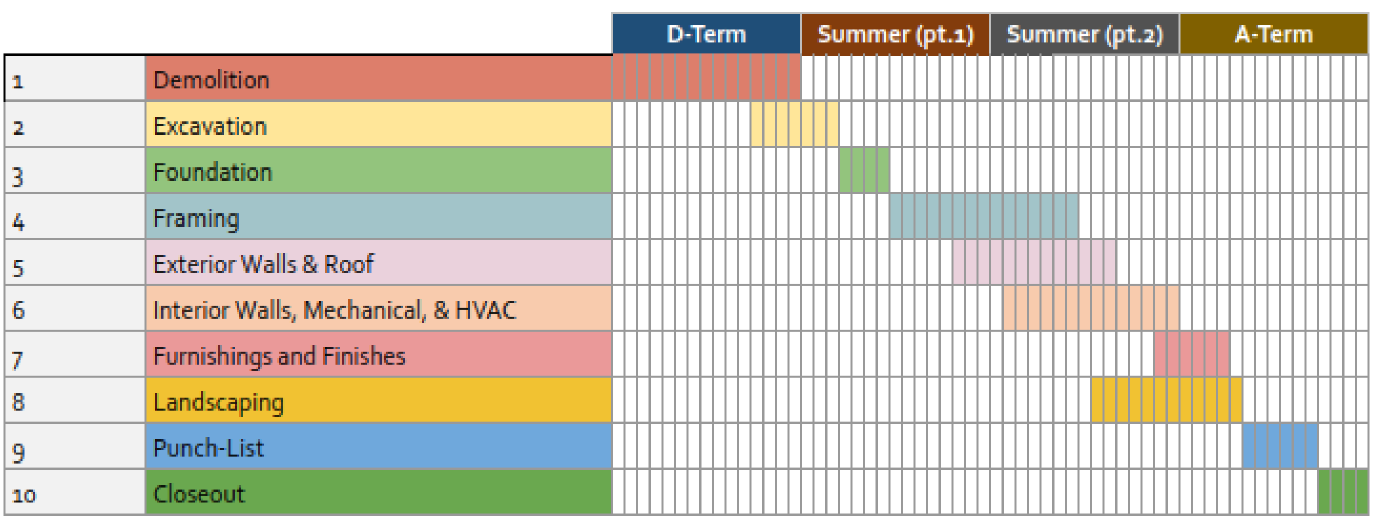


Figure 38: Rough Construction Timeline

Activity ID	Activity Name (Construction of the SHAFT)
Design	
Preconstruction	
1	Building Permits
2	Procuring Subcontractor Bids
Construction	
	Excavation
3	Backfill
4	Excavate for Foundation
	Foundation
5	Concrete Curing
6	Insulate Foundation
	Framing
7	Fabricate Steel
8	Erect First Floor Steel
9	Erect Second Floor Steel
10	Erect Third Floor Steel
11	Erect Fourth Floor Steel
	Exterior Walls & Roof
12	Install Roof
13	Install Curtain Walls
	Interior Walls, Mechanical, & HVAC
14	Insulate Stairs
15	Insulate Ducts and Piping
16	Install Electrical
17	Install Plumbing
18	Install Elevator
19	Install Flooring
20	Paint (prime)
	Furnishings and Finishes
21	Mechanical Finishes
22	Paint (finish)
23	Furnishings
	Landscaping
24	External Finishes and Grading
Punch-List	
Closeout	

Figure 39: General Activity List

5.0 Conclusions

The goal of this project was to create, design, and propose a socially accepted space by the students and faculty while also improving accessibility of two of the oldest buildings on WPI's campus. In order to do this, surveys of students and faculty discussing what they saw as the next improvement, precedent studies, programs, and evaluations of existing conditions were completed to design a space for the WPI community.

Through the project it was determined that Stratton Hall and the Project Center were the two buildings that students either did not use or thought needed to be improved. That in combination with a need for more offices, conference rooms for team meetings, and accessibility concerns lead us to design a space between and connecting these two buildings.

Discussions with campus planning facilities revealed that the best course of action to improve accessibility while also creating a space with more study spaces to appeal to students was the inclusion of an enclosed staircase and elevator in our design. The space itself features many gathering spaces for students and faculty with varying sizes to accommodate different numbers of people. Students and faculty alike find the idea of a connector endearing and even needed.

The designed building will approximately cost $4,800,000 and can be fast-tracked and completed in a relatively quick timeline (similar to that of the Kaven Hall renovation). Our recommendations and limitations regarding the proposed design follow.

5.1 Recommendations

We recommend that the WPI facilities department use this design and estimate as a reference point for a future Stratton Hall – Project Center connection. Our design incorporates a student perspective that will ensure high usage. Not only does the S.H.A.F.T. provide more heavily desired study and meeting spaces, but its location in central campus will also help with overcrowding in the Campus Center and Innovation Studio. Our team understands that the Project Center and Stratton Hall are not ADA compliant. The S.H.A.F.T. is a concept that expands on the code improvements in a realistic and optimized fashion. The voices of students should be heard and listening to what a desired space would look like for them is the best way to do that.

5.2 Limitations

Over the course of the project, the work was completed around several impactful limitations. One of those limitations was access to sufficient drawings and documents of the two existing structures, Stratton Hall and the Project Center. These are two of the oldest buildings on campus, so even with the help of the WPI Facilities and the Library Archives, most of what we had access to were incomplete drawing sets and random compilations of documentation. Although we took field measurements to determine the key information to construct a 3D model, a more comprehensive study of Stratton Hall and the Project Center will need to be completed. Furthermore, the information that was used for calculations and in the Revit models may be susceptible to measurement error. Likewise, with any project requiring demolition, a study of the building looking at the environmental impact needs to be further discussed and evaluated. Materials such as asbestos and lead are common in buildings of age. The cost estimate accounts for potential hazardous materials and environmental impacts that could be found but a further report of testing and determining the materials should be looked at and discussed. A project further looking at this can further develop the proposed construction.

The main focus of the project was the creation of the connection between the two buildings in order to improve accessibility. This still leaves work to be done Stratton Hall and the Project Center. Though it was not within the scope of this project, both of the existing buildings will have to be fully brought up to current building and fire safety codes. The accessibility of the buildings is taken into consideration, however updating sprinkler systems, fire walls and barriers, egress and restrooms might be necessary as well.

The cost estimate can only be as accurate as the level of detail in the reference drawings. without having drawings for Mechanical, Electrical, and Plumbing, detailed drawings for the structure, and documents for utilities, there can be considerable variance between actual conditions and the information that is shown in this report. The cost estimate provides a good basis to be improved upon with more and better information.

For the construction schedule, the timeline was made by using the durations of activities from Bartlett Hall, a similar project, but scaled down. This isn't an exact science and there is plenty of room for error, but it gave us an order-of-magnitude estimate on the time frame.

Finally, there are more economic and social factors that were not discussed or determined, this includes but not limited to the availability of classrooms if Stratton Hall were to undergo construction. This will need to be looked at in order to ensure there is enough space available on campus to conduct classes during construction. Noise from construction is another concern that wasn't considered, but it should be addressed due to the proposed project's proximity to other academic buildings, unlike the recently completed projects for the renovation of Kaven Hall and the construction of Unity Hall. Ultimately, the externalities of construction need to be further looked at and weighed against the benefit of the proposed connection.

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<u>Appendix</u>

Appendix A: Project Proposal

Building Redevelopment for Repurpose

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MQP

10/13/2021

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MQP Proposal for 2021-22 Academic Year

Abstract:

Recently, students have expressed displeasure in the current availability of study spaces in and around the campus. Meeting this need for more private group conference areas is tough to achieve without making significant changes to the current flow of campus. WPI's Stratton Hall and Project Center have been focal points of WPI's campus since the early 1900s; however, they are currently outdated. A renovation that addresses the need for more spaces will be endearing for all WPI students and faculty. Our project is a design proposal for a renovation and a building connection between Stratton Hall and the Project Center.

Professional Licensure Statement:

Professional Licensure is a certification that distinguishes certain individuals as qualified to work in their chosen profession. In architecture and engineering, it is important for practitioners to obtain professional licenses to minimize safety risks to the general public and to ensure that unqualified people are not doing jobs for which they are not qualified. Professional licensure enables the people that obtain them to seal and sign off on specific architectural, engineering, and construction documents. In addition, licensure enables individuals to obtain higher positions with room for continued growth in the field. Licenses are obtained in the United States from the jurisdiction where work is being done (i.e. one of the 50 states or territories). In the construction industry there are many types of Professional Licensure. Depending on whether one is becoming an Architect, a Civil/Field Engineer, or a Construction Manager/Superintendent, each has their own respective licenses.

In order to practice architecture, it is necessary to obtain a license from the state where the practice is being done. Each jurisdiction has different requirements; however, they all follow a similar general format. The first step to obtaining a professional license in architecture is to obtain an architecture degree in a NAAB-accredited program. Next, each applicant is required to gain professional experience under a professional architect and document it; all jurisdictions accept the *Architectural Experience Program* (AXP). Once completed, each applicant must successfully pass the ARE or the *Architect Registration Exam.* The final step would be completing any jurisdiction-specific requirement and then the *National Council of Architectural Registration Board* (NCARB) will need to be transmitted, recorded, and updated when needed.

The process to become a professional engineer is very similar to that of an architect. First, all applicants must complete a four-year degree program at an ABET-accredited engineering school. Once out of school, the applicant must complete the *Fundamentals of Engineering Exam (FE exam)*; this exam covers all topics discussed in general engineering classes unspecific to the focus of study. There are also popular versions of the FE exam that are discipline specific. Four years of progressive work must then be completed under a licensed and practicing professional engineer. Finally, after four years of practice, the applicant must complete the *Principles and Practice of Engineering Exam (PE exam)*. It is then when they can apply for a license in their respective jurisdiction and complete any additional requirements.

To become an occupational licensed supervisor for a construction manager or superintendent role, the state of Massachusetts requires a minimum of three years of field experience prior to registering for the *Construction Supervisor License test*. If the *Construction Supervisor License test* is passed, results will need to be sent and recorded by the Board of Building Regulations and Standards, this is also where renewals of licenses will occur.

Capstone Design Statement:

This project incorporates designing an addition connecting Stratton Hall and the Project Center on Worcester Polytechnic Institute's (WPI) campus. The team must design a space that evaluates the current flow of students through campus, addresses the need for more study spaces, considers and brings up to code both Stratton Hall and the Project Center, and develops a structurally sound addition, while planning and limiting the effect of any new construction has on campus and the surrounding neighborhood. To best provide WPI with a comprehensive plan for a design proposal and to fulfill the WPI capstone criteria for Accrediting Engineering Programs by the Accreditation Board for Engineering and Technology (ABET), the following six constraints will be considered:

Environmental:

Construction of all forms disrupts the natural flow of the environment surrounding it. From the destruction of existing habitats to the addition of added emissions from construction equipment and production of carbon dioxide. The city, in coordination with current building codes as well as its new sustainability plan, wants to ensure that wildlife is not directly impacted as well as the neighboring community with, for example, worsening air quality and degradation to land. The team will develop multiple design alternatives that encompass an initial environmental analysis of any construction that would take place. This analysis will be then considered in choosing a final design. Another constraint that directly impacts the nearby community is noise pollution. Construction creates a lot of noise that indirectly impacts the neighboring community. It is important to control to the best of the ability of the project in order to keep the community in good standing.

Health and Safety:

With demolition and renovation to older buildings there will be health and safety constraints that will be considered. The first constraint is dealing with hazardous building materials. It is imperative to find and determine hazardous building materials that were previously up to code such as asbestos and lead paints. Next, while working in a pandemic it is important to consider possible delays due to any unexpectant outbreaks. Finally, structural safety needs to be considered as well. The team will work in guidance with current building codes, the City of Worcester, WPI facilities, as well as current ASTM standards to ensure all safety guidelines are followed.

Constructability:

Given the current market of construction materials it is hard to determine whether scarce resources such as steel and lumber will be available during construction. Furthermore, another constraint related to Constructability is the location of the project. Although the project is zoned for Institutional use, it is imperative to continue to consult and follow the zoning ordinances for corresponding constraints and guidelines. Likewise, the location of the project makes it more difficult to continue to construct and build due to its close proximity to other buildings as well as being up on a hill. The Project Center and Stratton Hall also have different and dated exterior facades and building materials, so blending the two buildings together will pose both engineering and aesthetic challenges. The team will balance these constraints with most importantly making sure they are all structural sound in creating a final proposal.

Sustainability:

With renovating any building and conducting selective demolition, sustainability is an often common concern. New buildings are often more efficient and provide less waste. The City of Worcester has recently established a new plan called *Green Worcester Sustainability and Resilience plan.* The plan outlines that by 2045 each building needs to use 100 percent renewable energy and to limit emissions to an almost complete net zero. In proposing a design, the team will directly adhere to the general sustainability plans set by the City of Worcester as well as those set by WPI.

Social:

With any construction project there are multiple social externalities that need to be taken into consideration. The first social constraint that will need to be considered is where students and faculty are displaced because of the construction. The construction is predicted to take longer than a WPI summer of work so it is necessary to determine other means of temporary offices and spaces for faculty and students that can be affected. Furthermore, Stratton and the Project Center sit close to where West St. once crossed the WPI campus. This path is high traffic for students walking through campus and will likely be affected by the construction due to the space necessary for machinery and material storage. Finally, the project must be socially accepted as WPI has had push back on the Innovation Studio which was meant for students. The team will attempt to address current students and faculty concerns while still proposing a design solution and schedule which limits the amount of people displaced.

Economic:

Another constraint that the project needs to take into consideration is any economic issues that the project may encounter. First off, the school has a set budget as far as what can be built, and it is important to consider this when designing it especially since it is most likely being privately funded. Next, it is important to realize that with the scarce resources of materials such as lumber and steel, as discussed in previous sections, that prices will be elevated and can change drastically which can affect the economic constraints set by the Institution. The project team will take into consideration this constraint by evaluating the costs for each design and then use the analysis in making a decision in the final proposal.

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1.0 Introduction:

1.0.0. Design Problem:

Currently, WPI students have had a more difficult time finding collaborative study spaces. They have been using places such as the quad, the campus center, and off-campus apartments to hold serious group meetings. These spaces were not originally designed or intended for this use; however, it has become necessary because of the ever-increasing numbers of new students that are admitted each year. WPI has a need for a revised plan on how to address the limited availability of study spaces.

To further depict the need for improved study space options, WPI has currently enrolled 4892 students (as of fall 2021) which is an 18% increase since 2015. With limited additions to classrooms and study spaces besides the Innovation Studio (introduced in 2018), WPI has still not directly addressed collaborative study spaces in a long time. Students have expressed displeasure in the amount of study spaces for group meetings. Students feel as though there's enough areas for individual study but not for groups. While talking to the Vice President of Campus Planning Facilities, Eric Beattie, he characterized how the next steps for WPI is finding a way to increase the amount of study spaces without compromising other areas of the campus where space is still scarce.

Places such as Stratton Hall and the Project Center seem to be getting less and less traffic simply because of the outdated facilities. Stratton Hall is no longer up to code, with a need for an additional interior egress as well as an elevator to accommodate all students. The Project Center does not see many visitors simply because of the lack of clarity between students of its current use. In addition, the space between Stratton Hall and the Project Center is not used at all and provides nothing but a small cut through to an alleyway near the powerhouse. According to Eric Beattie, what has previously stopped WPI from connecting these two spaces in the past is the floors in each building do not line up and would require some sort of solution to address the split-level feature (Beattie, 2021).

1.1.0. Design Statement and Scope

To address the problems associated with the rising number of enrolled students, it is proposed that an addition to connect Stratton and the Project Center as well as an interior renovation that encompasses the need for more study spaces for students should be completed. The addition will include updated systems such as HVAC and plumbing to better improve comfortability for students, sustainability, as well as efficiency so the long-term cost associated with maintaining the building will be lower.

The first step in completing the renovation and addition of Stratton Hall and the Project center will be demolition of the existing interior. Since new layouts will be introduced in both buildings to make it one cohesive space, demolition will be necessary and an ongoing study of all structural components within the buildings will be conducted. Once demolition is complete, the new design of the building will feature a new entrance from West St. as well as an expanded gathering space on the first floor.

Next, more collaborative study rooms will be located on each floor in the addition. These rooms will provide students with spaces to work as a group or hold meetings with professors. These study rooms, similar to current tech suites in the library, will be on a reservation basis having their own Microsoft Office compatible device as well as a glass marker board and television.

In coordination with current building codes, it is necessary to design a building that has another form of internal egress as the existing exterior staircase is no longer up to code (Beattie, 2021). Also, the addition of an elevator that reaches all floors in Stratton is necessary to accommodate all students and faculty. Finally, in order to connect Stratton and the Project Center, it is important to realize that the floor elevations in the two buildings do not properly line up, and a design solution that makes the two spaces one cohesive space is important for the flow of both buildings.

2.0 Background:

2.0.1. Stratton Hall

WPI's Stratton Hall was built in 1894. It originally housed the Mechanical Engineering Department in its early stages. The original designer of the building, Earle and Fisher, designed a space that saw the first and second floors being an open and "undivided space," while the upper floors contained lecture halls, a library, recitation rooms, drawings rooms, a machine design room, and a model room. The building allowed WPI to expand into other engineering fields as it provided a home for the Mechanical Engineering Department until 1942 when Higgins Laboratories was commissioned.

Figure 1: Current Facade of Stratton Hall

Stratton Hall then was going to change to the home of the Civil Engineering department but in 1943 WPI was selected to become an officer-training school for the Navy V-12 program. The training saw the use of Stratton Hall as the quarters for Navy Seamen until 1946 where then the Civil Engineering Department moved in full-time up until 1954.

After 1954, Stratton Hall was where the Mathematics and English departments were found. Both departments continued to grow where it was apparent that other space was needed. Now the Mathematics department is the current and only tenant of Stratton.

More recently, Stratton Hall underwent renovations in 2011. The renovations done in 2011 improved the HVAC on the first floor as well as renovating to create a new computer lab. However, those renovations failed to realize and bring the building up to code as there is a need for an elevator, more overhead fire suppression as well as another means for interior egress (Beattie, 2021) .

2.0.2. Project Center

The Project Center was constructed in 1902. It was originally called the Foundry and served for the production of metal castings. The building was a blend of commercial and institutional purpose. Soon after opening, the Foundry was redesigned to be a high-tech forge shop that would go on to commercially benefit WPI for many years and be utilized by high-profile projects such as those led by Robert Goddard.

Figure 2: Current Facade of WPI's Project Center

Following the introduction of the WPI Plan, which shifted the focus of the institution to project-based learning, the Foundry became the Project Center. It now hosts the Career Development Center and the Interdisciplinary and Global Studies Division.

2.1.0 Construction and Design Consultation:

When designing a new building or facilities it is important to follow the general consultation process so the project that is being proposed will turn out to be an efficient use of resources for all parties involved. The first phase in designing is the pre-design phase.

2.1.1 Pre-Design Phase

This phase is where the architect or builder learns everything about the client, all the general requirements that they want or see in the building space. This information is usually gathered through either sit-down interviews with the owner specifically, focus-groups if the scope of the project is for a general group of people, or a survey if the scope of work is for thousands of people. Things to consider when conducting these preliminary screenings include previous use of the spaces, tenants' lifestyles, proximity to other facilities, as well as similar buildings. This is an important step because without the proper background, the design of the space will not be sustainable, and the use of the building will be discarded shortly after turnover.

Another key aspect in the creation and renovation of buildings are existing conditions. Existing conditions are tracked through old construction documents as well as creating new documents based on the site that work is being done to. For instance, surveying is often used to determine existing ground elevations, property line locations, and measurements of existing structures. Zoning is also a big input in the pre-design phase as any building or structure that is proposed will need to follow the requirements imposed by the town planning board as well as the town's zoning bylaw; this information is usually gathered and placed into a zoning summary report.

The final piece of pre-design involves programs and precedent studies. The building program for a project analyzes the main purpose of the building. Important things to consider when designing a building program include: number of occupants, activities of occupants, functions of spaces, spatial relations, building codes, furniture, and the clients' needs and requirements. The program will provide a basis for design that will be used when creating a floor plan and layout later in the design process.

The main purpose of this proposed project is to join two different building spaces cohesively to not only provide access to all students but also create a new space for students to collaborate. Categories being considered for this new space include, but are not limited to, an elevator, tech suites, computer lab, open study areas, lounge area, and lobby space. These various area types will allow for the main purpose of the building renovations to be achieved.

In addition, when creating a new building or redesigning existing buildings, it is always important to look at precedent studies as a part of the design process. Precedent studies provide a backbone to a new project by applying knowledge gained from past designs to the new one. They can provide inspiration, design concept generation, justification for design ideas, and explanation and communication of project ideas.

2.1.2 Schematic Design

After the background information regarding what is expected for the building is gathered in the form of programs it is then interpreted into a schematic design. The schematic design looks at the general design and shape of the building using the collected data from the programs previously generated. Schematic design typically does not include specifics about materials that are being used (i.e. types of floor finishes, ceilings, wall coverings, etc.) but instead allows the architect to generate multiple designs and floor layouts and propose them to the client. This is the stage where the design is the most fluid and can change very quickly depending on what is requested by the client. At this stage in the design process, the client can get a general feel of how much it'll cost to build the building based on similar previous buildings and a price per square foot. Cost estimates in this stage are very rough and not very detailed due to the lack of detail in the drawings.

2.1.3 Design Development

Design development is where the general structure and look of the building begin to finalize. Clients can always make changes, however, the later the changes are made the more consequences there will be in terms of money and time. At this stage, design specifications are prepared and a more detailed set of drawings including floor plans, interior, and exterior elevations, and sections of the building, are created. The main goal of this stage is to develop a more comprehensive cost estimate by facilitating and engaging subcontractors and using their pricing to determine the general cost of the building by those willing to help build. If the budget of the project is too great, this is the last real chance where the client and owner can make necessary changes to decrease general cost. At the end of this phase, building layouts and dimensions are finalized with most materials being determined. Many times, structural engineers, civil engineers, and MEPs usually join the project and produce their own drawings of what will be needed for the building to be constructed with all the design requirements.

2.1.4 Construction Documents

This phase seems simple; however, it is the longest due to the necessity of getting everything correct and precise. General contractors will look at these drawings and send RFIs (request for information) or RFPs (request for proposal), this is where the design is not clear, information is missing, or the general contractor believes constructability is in question and would rather build it a different way. Once all the specifics are sorted out, the documents are finalized and ready for final subcontractor bidding as well as obtaining building permits for construction.

2.3.0. Building Codes

For this proposed project the main codes that will be utilized are the *780 CMR* (*Massachusetts State Building Code* based on the 2015 IBC), *527 CMR* (*Massachusetts Fire Code*)and the *248 CMR (Massachusetts Plumbing Code)*. These codes provide guidelines that must be followed when creating a new building or updating existing ones.

2.3.1. Egress Implications

An egress is a path from inside a building to an exterior point of safety. Elements of means of egress come in several different forms that include doors, windows, ramps, staircases, and fire escapes. Although each one of these means of exit can be considered a type of egress, they must meet the required specifications in the city or state of the building. An egress can be broken down into three components: the access, which is the entrance to the point of egress; the exit, the exact method of getting out of the building; and the exit discharge, the location that the point of egress leads to. To ensure a safe and accessible egress, the *Massachusetts State Building Code* has requirements for both size and location of doors, windows, ramps, and fire escapes.

For the Stratton Hall-Project Center project, several code issues regarding acceptable points of egress will need to be fixed. The *Massachusetts State Building Code* requires that when renovations that affect 30% of the building occur, the scope of work has to include improving the building to the code set by the city. Stratton Hall has an exposed central staircase, a fire escape, and a back door that lacks the proper accessibility. By proposing a connection to another building, the work done on the building would make it necessary to include updating all points of egress in Stratton Hall.

The fire escape is the most glaring issue with the egress routes in Stratton Hall. New construction rarely uses fire escapes because they can be dangerous and compromised by weathering. Advancements in fire protection engineering have allowed for safer alternative egress routes from high levels in a several story building.

2.3.2. Fire Protection

Fire Code exists to protect building occupants from fires by providing mandatory design standards that prevent fire from spreading and allow occupants to exit quickly. Depending on the type of construction (commercial, residential, etc), fire codes will vary to serve the building as best as they can. A smaller house will not have the occupancy that a skyscraper does and so enclosed staircases with a 2-hour fire barrier, for example, would not be necessary. There are many forms of fire protection engineering that can be incorporated into the design of a new building. Some examples are fire barriers, sprinklers, closed layouts, fire doors, and egress routes.

Stratton Hall and the WPI Project Center were built prior to the development of modern fire code standards. The two buildings rely on sprinkler systems for fire control and do not have the proper enclosures for points of egress. However, unlike modern designs, the lack of open concept floor plans helps with controlling the spread of fire by providing compartmentation. As part of the redesign process, Stratton Hall and the WPI Project Center will be brought up to current fire codes.

2.3.3. Plumbing and Restrooms

Restroom requirements vary depending on the type of building and the area. If the building is commercial or used as a workspace, there may need to be a certain number of toilets for the number of people that will be using the space. A general estimate of the size and quantity of restroom facilities in larger buildings such as institutional ones like the Stratton Hall-Project Center building; a general estimate can be made based on traffic predictions. With the introduction of a new space increasing the traffic in both existing buildings, there is cause for another look into the restroom capacities.

The *Massachusetts Plumbing Code* dictates fixture and piping size and quantities based on the restrooms in buildings. As the two buildings exist, the plumbing is up to code for the current fixtures. The introduction of more restrooms or water fountains will change the standards for the building plumbing system.

2.3.4. Accessibility

Building accessibility is the creation of space that is designed to be user-friendly for all people including those who are physically disabled. These include people with hearing or vision impairments and people who use wheelchairs, motorized scooters, canes, etc. Improving the accessibility of buildings is about removing barriers to promote equality. It affects the whole layout of buildings in terms of flow in the change of elevation, not just at the entrance. Common features that promote accessibility are ramps, power-assisted doors, elevators, and wide doorways.

Stratton Hall and The Project Center were built around the 1900, long before accessibility standards were in place. Therefore the two buildings have no elevators, lack quality ramps, and have inefficient stairways. The stairways fail to accommodate for students that are handicapped as well as making it extremely difficult to move hard to carry items upstairs or downstairs. A revised plan for student and faculty flow vertically throughout the buildings will need to be addressed.

2.4.0. Design Softwares

The design and construction of a modern building project incorporates many different softwares throughout the entire process. From designing to determining constructability to scheduling to estimating, the entire pre-construction process through the use of softwares expedites the process of construction.

2.4.1. Revit

AutoDesk Revit is a 3D building information modeling software that can be used to design structures and systems within buildings. It brings together all disciplines of construction from architecture to engineering. It can be used by creating a 2D model of certain components such as floor plans and elevations and then translate that into a 3D model. One key aspect of Revit is its compatibility with other AutoDesk softwares. Revit is compatible with Civil 3D which can directly import and combine accurate site plans into a building design. From this Revit can also generate a simulation of the construction using Navisworks. Navisworks takes the materials and plans from Revit, generates a schedule and simulates each construction phase that the building will undergo until its completion. Not only does Revit aid in construction simulations but it can also aid in energy efficiency and energy analysis by allowing input of site-specific weather and climate data and simulating how the building would be affected by it. Another important feature of Revit is material takeoff. Revit auto-generates a takeoff list of all materials and components of buildings; this is important in order to create a proper cost estimate. Revit is important to ensure that the design and structural components align properly. The group will use Revit to help design and create a 3D Building Information Model of the renovation.

2.4.2. Primavera

Primavera P6 is a construction scheduling software. It is used to create comprehensive schedules for general construction to follow. It creates a critical path where it is easy to see activities to shorten or change the length of the project if it is off schedule. It is different from the schedule Revit generates as this takes into consideration actual subcontractors' schedules and time allotted to certain tasks rather than just a general simulation. Primavera also allows for resource-leveling which can help balance certain trades within the construction of buildings. Once all information is imported into Primavera, it displays the total duration of the project, total float (the amount of time an activity can be delayed without delaying the whole entire project), as well as a Gantt chart for ease of the reader. The group will use Primavera to schedule and determine the total duration of the renovation.

2.4.3. Excel

Microsoft Excel is a spreadsheet software that can be used for a variety of purposes, from performing basic cost estimates by importing material take-off from Revit and associated prices with each specific material to helping determine egress calculations for fire protection. Excel is a multidimensional software that has multiple ways it can be used to do repeat calculations in an orderly manner through the input of set equations and variables. Excel will be used to help organize information as well as determining load, egress, and other calculations for the proposed design.

2.4.4. Bluebeam

Bluebeam is a PDF reader software specifically made for the construction industry. It allows for architects, general contractors, and engineers to collaborate virtually. It allows whoever is using it to do quantity take-off from scaled drawings. This is an important feature, especially when preparing a cost estimate. In addition, it allows the user to highlight and markup specific locations of documents where points of clarity are needed (i.e. RFIs). Bluebeam will be important to use especially when reviewing existing conditions on old construction documents as it allows you to label points of interest.

2.4.5. GIS

GIS, also known as Geographic Information System, is a software that creates, uses, interprets, and analyzes maps. GIS assigns elevation data to existing maps in order to give a more detailed view of possible places where excavation is needed to properly grade a site. GIS data can be directly imported into Autodesk Civil 3D so virtual site grading can take place. GIS is important, especially when dealing with connecting two or more buildings as it allows the user to determine whether construction is practical based on the ground alone. The group will use GIS to properly determine and simulate grading the site for the proposed design.

2.4.6. AutoCAD

AutoCAD is a 3D modeling software that can be used to design various components of buildings. It is typically used to design structural components such as the building foundations, structural beams and columns, and certain HVAC systems. AutoCad will be able to help model-specific components of any renovation of building construction.

2.4.7. Sage Estimating

Sage Estimating, previously known as Timberline, is construction software that allows you to estimate the cost of the building based on trades. Typically CSI MasterFormat is used to organize a cost estimate but in some instances, the Uniformat can be used to provide a cleaner cost estimate. To create an estimate, a material takeoff is input into Sage with the corresponding line items associated with trades. Using previous estimates and the Sage database, cost per unit is generated, ultimately creating total cost. Sage also allows users to create estimates based on square foot cost; this is beneficial when drawing details are minimal and detailed material takeoff cannot always happen. Sage will be used to determine the estimated cost of the proposed design.

WPI Students have stated their desire for additional study spaces. Stratton Hall and the Project Center are two long standing, historic buildings in the heart of the WPI campus. With old-fashioned brick facades and interior layouts, there is precedent for design that compliments the aesthetic and addresses the fire and ADA code shortfalls, while providing another study-focused area in a central location. Through a general construction consultation, improvements to both Stratton Hall and Project Center will be proposed.

3.0 Methods and Deliverables:

The goal of our project is to create a space that successfully encompasses the needs for private conference areas for both the students and faculty. Generally speaking, construction consultants follow a general format from the pre-design phase to the construction phase in order to properly account for their clients' demands and needs. Figure 3 shows the general timeline of a design/build firm.

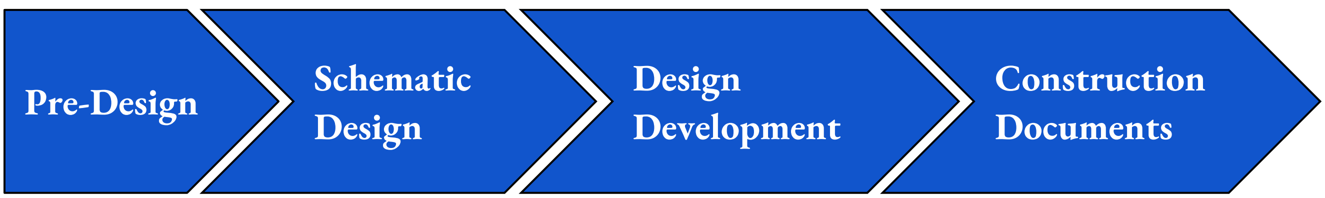

Figure 3: Overview of general timeline for design/ build firm

Most buildings that will be proposed for completion typically occur at the end of the schematic design phase or at the beginning of the design development phase; this is where the owner can typically see the whole project coming together. To properly propose a renovation and connection between Stratton Hall and the current Project Center, most pre-construction work, except for bid solicitation, will be completed to determine efficacy. Our objectives and methods to do so are shown in Figure 4.

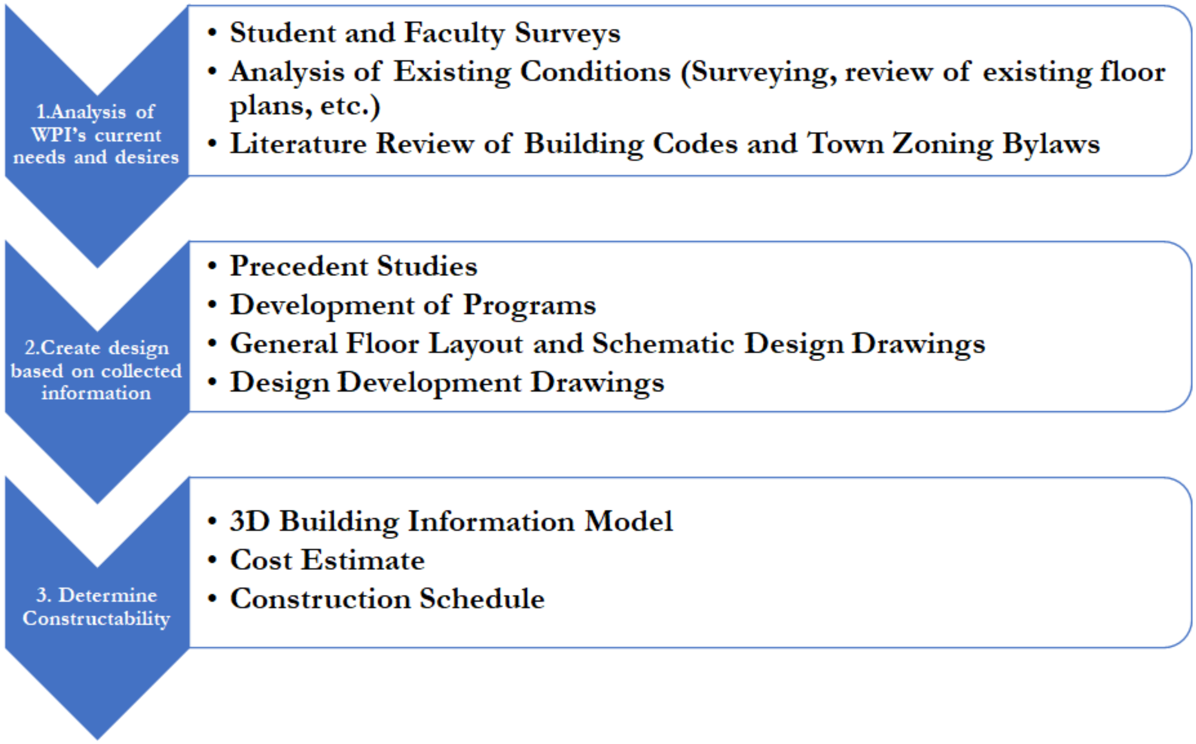

Figure 4: Overview of project objectives and methodology

<u>3.1.0. Pre-Design</u>

The first phase in any construction is pre-design. Pre-design encompasses the whole scope of the project, from who the project is being built for, to the interpretation and analysis of existing conditions and zoning bylaws, to what are possible design options and or criteria of the project. For the purpose of our project, an initial survey of students and faculty will be completed to gauge interest and determine what they want from the space, then a comprehensive analysis of existing conditions and zoning bylaws will be conducted, followed by the creation of programs based on precedent studies and previous data.

3.1.1. Survey

The first step in developing a proposal for construction is determining what is desired by the clients. In the case of Stratton Hall and the Project Center, the clients will be WPI, including current students and faculty. The goal for our project is to create a space that all students desire or feel the need to have based on the current climate around campus. To gauge the general interests of WPI students a survey will be conducted. The survey will ask students about the general experiences related to Stratton Hall and the Project Center, current availability of study spaces, desired locations of study on campus for both group work and private study, and a brief analysis of what academic buildings they feel can be improved on or modeled after (i.e. the layout of Gordon Library). The survey will be made on Google Forms and will be sent around local organizational message boards as well as be available throughout campus, via a QR code, for students to answer at their convenience. The following is a more detailed list of the questions that will be asked to students.

Table 1: List of student survey questions.

Have you personally had classes in Stratton Hall?
Have you personally been in the WPI Project Center located next to Stratton?
If you needed a place to study on Campus for an exam or project work where do you go?
If you needed a place to study in a group on Campus for an exam or group project work where do you go?
Do you have difficulties finding spaces to study?
Is there any space on campus where you see a need for improvement in terms of flow, accessibility, comfortability, etc. ?

The general surveying process will be similar for faculty to that of students. They will be asked questions related to any improvements that they see or desire for the campus to have shortly, as well as more specific questions for current teachers being relocated due to the renovations on Kaven Hall to determine the impact and effect it has had on them and their productivity.

Table 2: List of Faculty Survey Questions

Is there any space on campus where you see a need for improvement in terms of flow, accessibility, comfortability, etc. ?
If a renovation to Stratton Hall and the Project center were to happen, what do you want to see in the space?
Were you affected by the ongoing renovation to Kaven Hall? If so, can you talk about your experience?(How has it impacted your productivity, is there anything WPI could have done better to mitigate the effects of having to relocate classes and personal offices?)

The data collected will then be gathered into one Excel file and then interpreted to see what are common connections between students and faculty with the goal in mind of creating a program from their shared responses.

3.1.2. Existing Conditions

To design an addition or a renovation to a building, existing conditions must be examined. There is information such as elevations, HVAC and plumbing locations, dimensions, and many others that cannot be overlooked before construction begins. There are two locations where documentation of the Project Center and Stratton Hall is stored: The WPI Library Archives and WPI Facilities. Available drawings will be obtained for both buildings, whether they are original or for renovation plans, as they show some of the necessary information for our design and calculations. Another method of examining the existing conditions is by physical survey. This will help us specifically determine the exterior data such as the total distance data and the elevation data of the Project Center and Stratton so that the new addition can be lined up correctly with the two existing structures.

3.1.3. Zoning and Bylaws

Before making any renovations or additions to a building in the Worcester area, one must first seek approval from the City and more specifically the City Council. The City keeps track of all land parcels and the additions and changes to them. The Council assures that building plans are safe and up to code before any work is completed. The City of Worcester zoning ordinance states that, "No building, structure or land, in any district, may be used, erected, altered or expanded, in whole or in part, for any use not expressly permitted in that district unless as a permitted accessory use pursuant to Article IV, Section-8." This means that any proposed addition or change to either Stratton Hall or the Project Center will have to first get approved by the city planning board before beginning construction. In order to adhere to current zoning, a literature review will be done discussing current zoning of the proposed construction.

3.1.4. Special Conditions

This proposed project will include many unique design aspects that will require custom work in order to complete the goals of the project. The two buildings are both at slightly different elevations. This means that the created section between the two buildings will have to find a way to connect the different leveled floors. This will also include finding a way to give all floors of both buildings elevator access. Another issue specific to this project is the electrical, plumbing and HVAC systems. Since there are two buildings being connected, each with its own respective electrical, plumbing, fire and HVAC systems, the newly installed systems for the new connection will need to be connected to either one of the buildings or be on its own independent system.

3.1.5. Precedent Studies

Precedent studies serve as an inspiration for building design in the pre-design phase. In order to find relevant precedent studies, different aspects of the project are picked to focus on. The two main categories for research will be connecting existing buildings and different types of group study spaces. These categories are selected because along with making these buildings accessible one of the main purposes when connecting Stratton and the Project Center is to create a new study space on campus where students can meet and collaborate with their team. Various buildings are looked at during research, taking into consideration the social and cultural aspects, the geometric form and mass of the building, the purpose of the building, the building materials, etc.

3.1.6. Building Program

In order to build a program, background information will first be gathered. This information includes the results from the student and faculty surveys, the precedent studies, the client's needs, and the building requirements. The building requirements combined with the client's needs will dictate what types of spaces will be put into the program. This might include office spaces, restrooms, an elevator, stairs, study spaces, etc. The group will use the results of the student and faculty surveys in order to determine how much of the building will be designated to each space. The precedent studies will help determine how to properly utilize the new space and have it properly flow into the existing buildings. It will allow for the floor area to be used to its fullest extent and will provide the proper types of spaces for the building that work well together.

3.2.0 Schematic Design

The next phase in any construction consultation would be the creation of schematic design documents. The schematic design typically includes some sort of exterior rendering and floor layouts. Costs can be estimated from these plans, but they are limited by using prior estimates. Schedules can also be created.

3.1.1 Floor Plan

When designing the floor layouts, the previously created program will be utilized to provide a backbone for various floor plan layouts. Along with the program, the layouts also must define the functional spaces, enable good flow between spaces, and comply with the building code. Taking all of this into consideration, the group will collaboratively design two to three floor layouts to compare different possibilities. These designs will start off as hand sketches based on the program, and then softwares such as Revit and AutoCAD will be used to provide more precise and in-depth layouts. As a group, we will analyze the benefits and setbacks to each layout in order to decide which of these layouts best meets the client's needs. This can be done in a few different ways including creating categories and rating each layout in each category to determine which design is overall the best per the rated criteria, having students and faculty give their inputs on the design, and using those results to determine the final design, or creating a Venn diagram to compare the designs directly to one another and determine the final floor layout. The floor layout that is decided on will be selected for the schematic design floor plans for the project.

3.2.2 Elevation Plans

To design the addition we need to determine the floor elevations on each of the existing structures. If there are differences between the floor elevations then that would affect the floor plans. The elevations will be mapped with two methods. The first of which would be by examining the existing drawings. Although sparse, WPI has some copies of exterior drawings that include elevation cuts with dimensions. The second method is surveying. We will use a total station and GIS software to look at the elevations of Stratton and the Project Center from the exterior. This method will also help verify the accuracy of the drawings.

However, it may be difficult to get accurate floor elevations due to the total station needing to be outside to properly function. If that is the case, then another method that could be implemented would be to determine the height of the windows on the outside of the building using the total station or another measurement tool, measuring the distances from the floor to the window sill on the inside of the building, and then subtracting those distances from the window elevations to get the most accurate floor elevations.

3.2.3 3D Modeling

From the floor plan generated from the design development drawings, we will create a 3D model of the connection between Stratton Hall and the Project Center. To generate a 3D model, Revit will be utilized. Building materials will be selected based on the existing materials within Stratton Hall and the Project Center as well as incorporating information gathered from precedent studies. If the general materials are different for finishes, for example the carpets are different, then materials will be selected based off of materials selected at one of WPI's newly renovated spaces such as the Innovation Studio, Kaven Hall, or the new academic building. Once the building is generated, the exact location will be input into Revit so an Energy Analysis of the building can take place as well as determining the amount of natural light that will be able to hit the building throughout the day.

Once the Revit model is completed, the file will be moved to Navisworks where a simulation of the construction will take place with multiple phases. Navisworks will allow us to generate a basic schedule of the components that we included in the Revit file, but will not create a detailed enough schedule to follow for construction purposes. Revit will also generate a list of materials that can later help with the general cost estimate of the building.

3.2.4. Scheduling

Once the 3D model and floor layouts are finalized, we will use the information gathered from the Navisworks' schedule in connection with previous building schedules for renovations and new building construction on campus, such as the Bartlett Center, Innovation Studio, and Kaven Hall to create a comprehensive list of activities that will be needed for construction. The list will then be input into Primavera P6 and will, in combination with a literature review of construction tasks and their duration, be arranged and sorted.

The schedule will also include selective demolition of Stratton Hall and Project Center as well as other site-specific tasks. The schedule will display the total duration of the project from demolition to final punch list items.

3.2.5. Cost Estimate

Similar to the schedule, the cost estimate will be dependent on the materials used in the 3D model as well as the general floor layouts that are finalized. As previously mentioned Revit will generate a material takeoff list of all the materials that will be used; however, this often does not include all materials the building will need. Using the schedule in combination with previous estimates, a general idea of what needs to go in the building will be included as well as general allowances for items such as emergency signage, or demolition that aren't explicitly outlined or easily quantified in the plan. For this reason, Sage Estimation will be used. Sage allows us to take the material takeoff from Revit and enter it directly by just assigning a price per unit. All other items will be inputted as well for the whole entire structure. The cost will not just be for the materials but also for the installation and general contractor fees as well as other back-page items in the estimate.

Our final deliverables will include the floor layouts, the 3D model of the renovation, a construction schedule and cost estimate, as well as a general analysis discussing constructability

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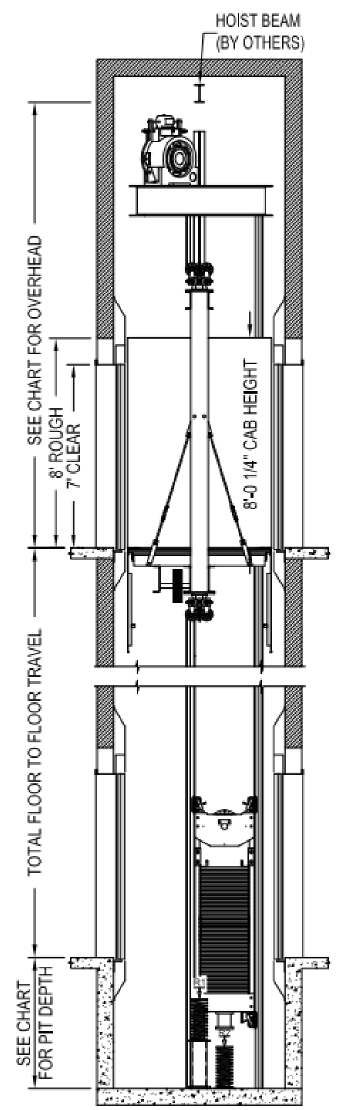
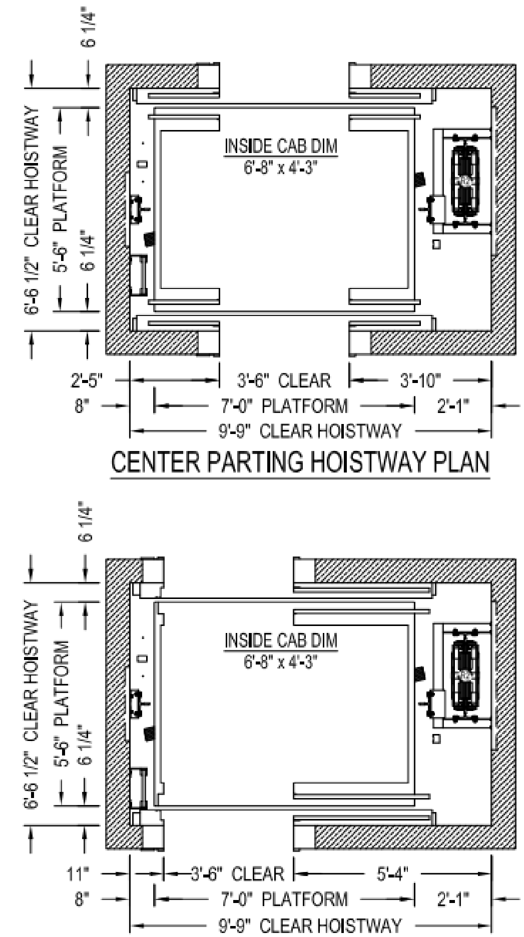
Appendix B: Schumacher MRL Elevator Specification Sheet



HOISTWAY ELEVATION VIEW



Capacity	Max Speed	Minimum Pit Depth	Minimum Overhead	Cab Height
2500 lbs.	200 fpm	5'0"	17'0"	8'0"
2500 lbs.	350 fpm	5'6"	17'6"	8'0"
2500 lbs.	400 fpm	5'9"	17'9"	8'0"
2500 lbs.	500 fpm	6'3"	18'6"	8'0"

* CONSULT A SCHUMACHER REPRESENTATIVE FOR CLASS C ELEVATOR HOISTWAY SIZE, PIT, AND OVERHEAD DIMENSIONS.

Schumacher Elevator Company
ONE SCHUMACHER WAY - DENVER, IOWA 50622

MRL TRACTION
ELEVATION & PLAN VIEW

CAPACITY 2500 lbs. | 25MRLSS2E14
SINGLE SLIDE & CENTER PARTING

Appendix C: Detailed Cost Estimate

Project Name: WPI's "SHAFT"							
DESCRIPTION	QTY.	UNIT	UNIT COST (MATERIAL)	TOTAL (MATERIAL COST)	UNIT COST (LABOR)	UNIT COST (MAT.+LAB)	TOTAL COST (MAT. +EQUIP. +LAB.)
DIVISION 01 - GENERAL REQUIREMENTS							
MOBILIZATION	1	LS					
BOND & INSURANCE	1	LS					
SUPERVISION	1	LS				$ 7,000	$ 7,000
SUBMITTALS & SAMPLES	1	LS				$ 6,500	$ 6,500
TEMPORARY FACILITIES & CONTROLS	1	LS				$ 5,000	$ 5,000
PROJECT SCHEDULE	1	LS				$ 5,000	$ 5,000
OFFICE OVERHEADS	1	LS				$ 6,000	$ 2,000
CLOSEOUT PROCEDURES	1	LS				$ 3,000	$ 3,000
Exterior Mockups	1	LS				$ 25,000	$ 25,000
Winter Weather Conditions	1	LS				$ 10,000	$ 10,000
Final Cleanup	1	LS				$ 15,000	$ 15,000
Window and Glass Cleaning	1	LS				$ 7,500	$ 7,500
						Subtotal =	**$ 86,000**
DIVISION 02 - EXISTING CONDITIONS							
Existing CMU Selective Demolition and Removal	**3224**	**SF**			$ 15.00	$ 15.00	$ 48,360
Existing Gas Pipeline Removal and Capping	**2**	**EA**			$ 5,000	$ 5,000	$ 10,000
Temporary Scaffolding	**5**	**days**			$ 150	$ 150	$ 750.00

Relocation of existing HVAC Systems (Stratton and Project Center)	**1**	**LS**			$ 15,000	$ 15,000	$ 15,000
						Subtotal=	**$ 74,110**
DIVISION 03 - CONCRETE							
SLAB							
4" 3500 PSI P.C. SLAB W/ 6X6X10 WWR	1304	SF	$ 11.0	$ 14,344.0	$ 4.8	$ 16	$ 20,603
6 MIL POLY-VAPOR BARRIER	1304	SF	$ 1.0	$ 1,304.0	$ 0.5	$ 2	$ 1,956
COMPACTED SUBGRADE	1304	SF	$ -	$ -	$ 3.0	$ 3	$ 3,912
FOOTING							
42" X 42" X 18" CONC. FOOTING	10.889	CY	$ 370.0	$ 4,028.9	$ 160.0	$ 530	$ 5,771
36X36X12 CONC. FOOTING	5.3333	CY	$ 370.0	$ 1,973.3	$ 160.0	$ 530	$ 2,827
24 X 16 CONT. FOOTING	15.369	CY	$ 370.0	$ 5,686.5	$ 160.0	$ 530	$ 8,146
PILE CAP							
WALL							
10" THK. 3500 PSI CONC WALL	260	CY	$ 370.0	$ 96,200	$ 160.0	$ 530	$ 137,800
						$ -	
FORMWORK							
FORMWORK REQUIRED FOR FOOTING	1304	SF	$ 3.0	$ 3,912	$ 5.0	$ 8	$ 10,432
						Subtotal=	**$ 192,700**
DIVISION 04 - MASONRY							
10" Exterior Masonry Wall	2496	SF	$ 20.00	$ 20.00	$ 7.00	$ 27.00	$ 67,392
Loose Lintels	48.00	LF	$ 5.00	$ 5.00	$ 7.00	$ 12.00	$ 576
Install Loose Lintels	48.00	LF	$ -	$ -	$ 10.00	$ 10.00	$ 480

Brick Façade	1248.00	SF	$ 15.00	$ 15.00		$ 5.00	$ 6,240
						Subtotal =	**$ 74,688**
DIVISION 05 - METALS							
Metal Decking -22 GA	6024	SF	$ 7.8	$ 46,686.0	$ 2.3	$ 10	$ 60,240
MISC. METALS						$ -	
16 GA FLASHING	131	LF	$ 3.2	$ 419.2	$ 2.5	$ 6	$ 747
MISC. Steel Connectors (5% of total steel tonnage cost)	1	LS				$ 8,776	$ 8,776
BEAM + COLUMNS						$ -	
Steel Tonnage	27	TON	$ 6,500.0	$ 175,500.0	$ 1.0	$ 6,501	$ 175,527
						$ -	
STAIRS						$ -	
Metal Pan Stair	5	FLTS	$ 15,000.0	$ 75,000.0	$ 1.2	$ 15,001	$ 75,006
2 1/2" DIA STAINLESS STEEL HAND RAIL AT STAIRS	160	LF	$ 15.0	$ 2,400.0	$ 12.0	$ 27	$ 4,320
						Subtotal=	**$ 324,616**
DIVISION 06 - WOOD,PLASTICS AND COMPOSITES							
FRAMING						$ -	
Roof Blocking	156		$ 5.0	$ 780.0	$ 10.0	$ 15	$ 2,340
Window Blocking	96		$ 5.0	$ 480.0	$ 10.0	$ 15	$ 1,440
						$ -	
STUDS						$ -	
2X6 STUD WALL @ 16" O.C. NO. OF STUDS @ 9'-0" HT. = 111	1043	LF	$ 6.0	$ 6,258.0	$ 4.5	$ 11	$ 10,952
						$ -	
PLATES						$ -	
2X4 DOUBLE TOP AND SINGLE BOTTOM PLATE	150	LF	$ 3.0	$ 450.0	$ 1.0	$ 4	$ 600

2X6 DOUBLE TOP AND SINGLE BOTTOM PLATE	590	LF	$ 3.0	$ 1,770.0	$ 1.0	$ 4	$ 2,360
						$ -	
BEAMS						$ -	
1 3/4" X 11 7/8" ML LVL	33	LF	$ 6.2	$ 204.6	$ 4.6	$ 11	$ 356
						$ -	
HEADERS						$ -	
2X10 HEADER	104	LF	$ 2.8	$ 291.2	$ 3.4	$ 6	$ 645
2X8 HEADER	22	LF	$ 2.6	$ 57.2	$ 3.3	$ 6	$ 130
						$ -	
SUB FLOORING						$ -	
SHEATHING AT JOISTS W/ 8D NAIL @ 16" O.C.	6043	SF	$ 1.7	$ 10,273.1	$ 2.1	$ 4	$ 22,963
						$ -	
SHEATHING						$ -	
5/8" EXTERIOR GRADE SHEATHING W/ (2) = 16 D @ 24" O.C.	1248	SF	$ 1.8	$ 2,246.4	$ 1.4	$ 3	$ 3,994
5/8" THK. CDX PLYWOOD SHEATHING W/ 8D NAIL @ 16" O.C. AT ROOF	1364	SF	$ 1.8	$ 2,455.2	$ 1.4	$ 3	$ 4,365
						$ -	
BLOCKING						$ -	
2x Fire Blocking at interior walls	593	LF	$ 2.5	$ 1,482.5	$ 2.0	$ 5	$ 2,669
						$ -	
TRIM						$ -	
Interior trims at openings	900	LF	$ 3.0	$ 2,700.0	$ 2.3	$ 5	$ 4,770
						$ -	
MILLWORK						$ -	
						$ -	
COUNTERTOP						$ -	
Bath Counter	40	SF	$ 30.0	$ 1,200.0	$ 10.0	$ 40	$ 1,600
						$ -	
CABINETRY						$ -	

Built-in-Bench with Table	1	EA	$ 5,000.0	$ 5,000.0	$ 1,000	$ 6,000	$ 6,000
						Subtotal=	**$ 65,183**
DIVISION 07 - THERMAL AND MOISTURE PROTECTION							
						$ -	
INSULATION						$ -	
2" RIGID FOAM INSULATION 24" HORIZONTALLY AND 12" VERTICALLY AROUND PERIMETER OF NEW SLAB	156	SF	$ 3.0	$ 468.0	$ 5.0	$ 8	$ 1,248
						$ -	
SEALANT						$ -	
SEALANT AT DOORS	900	LF	$ 0.5	$ 450.0	$ 0.5	$ 5	$ 4,500
SEALANT AT WINDOWS	112	LF	$ 1.0	$ 112.0	$ 3.0	$ 5	$ 560
						$ -	
INSULATION						$ -	
Rigid Insulation - Acoustic - Auralex - Interior Walls	4451	SF	$ 5.5	$ 24,480.5	$ 4.0	$ 10	$ 42,285
						$ -	
R-19 Insulation at Exterior Walls	4992	SF	$ 5.5	$ 27,456.0	$ 5.0	$ 11	$ 52,416
Rigid Insulation - Acoustic - Auralex - Ceilings	6040	SF	$ 5.5	$ 33,220.0	$ 4.0	$ 10	$ 57,380
4mm Air Vapor Barrier	1352	SF	$ 4.0	$ 5,408.0	$ 0.5	$ 5	$ 6,084
R-30 Insulation at Roof	1352	SF	$ 5.0	$ 6,760.0	$ 1.2	$ 6	$ 8,382
Ice & Water Shield at Roof	1352	SF	$ 5.0	$ 6,760.0	$ 1.0	$ 6	$ 8,112
SEALANT						$ -	
Top and Bottom Caulking and Sealing at Gypsum Board Walls	2043	LF	$ 1.0	$ 2,043.0	$ 0.5	$ 2	$ 3,065
						$ -	

Caulking at tile transition and dissimilar surfaces	263	SF	$ 3.0		$ 5.0	$ 8	$ 2,104
						$ -	
SEALANT						$ -	
TOP AND BOTTOM SEALANT AT WALLS	720	LF	$ 0.5	$ 360.0	$ 0.5	$ 1	$ 720
ROOFING						$ -	
EPDM Membrane Roofing	1566	SF	$ 3.5	$ 5,481.0	$ 1.5	$ 10	$ 15,660
						Subtotal=	**$ 202,515**
DIVISION 08 - OPENINGS							
						$ -	
GLASS AND GLAZING							
Curtain Wall - System	1941	SF				$ 175	$ 339,675
Exterior Storefront System	196	SF				$ 250	$ 49,000
Glass Partitions	1839	SF				$ 50	$ 91,950
DOORS						$ -	
						$ -	
Door Hardware	21	EA	$ 1,000.0	$ 21,000	$ 200.0	$ 1,200	$ 25,200
3'-0" X 7'-0" HM Door-Single	9	EA	$ 550.0	$ 4,950	$ 200.0	$ 750	$ 6,750
6'-0" X 7'0" HM Door-Double	6	EA	$ 1,200.0	$ 7,200	$ 200.0	$ 1,400	$ 8,400
3'-0" X 7'-0" Frameless Glass Door	24	EA	$ 2,200.0	$ 52,800	$ 500.0	$ 2,700	$ 64,800
3'-0" X 7'-0" Exterior Store Front Doors	2	LVS	$ 3,000.0	$ 6,000		$ 3,000	$ 6,000
FRAMES						$ -	
3'-0" X 7'-0" HM Frame - Single	9	EA	$ 550.0	$ 4,950		$ 550	$ 4,950
6'-0" X 7'-0" HM Frame - Double	6	EA	$ 650.0	$ 3,900		$ 650	$ 3,900
WINDOWS						$ -	
3'-0" X 5'-3" Fixed Transom Window	7	EA	$ 2,500.0	$ 17,500	$ 400.0	$ 2,900	$ 20,300

						$ -	
						Subtotal=	**$ 620,925**
DIVISION 09 - FINISHES							
						$ -	
FLOOR FINISHES						$ -	
BASE						$ -	
Rubber Base - (Entry Vestibule, Offices, Conference Rooms, Lobbies, Stairs)	1115	LF	$ 3.0	$ 3,345	$ 2.5	$ 6	$ 6,133
Ceramic Tile Base - (Bathrooms)	99	LF	$ 10.0	$ 990	$ 6.0	$ 16	$ 1,584
FLOORING						$ -	
Stainless Steel Entrance Flooring - EF01 (Entry Vestibule)	82	SF	$ 35.0	$ 2,870	$ 20.0	$ 55	$ 4,510
Carpet Tile - CPT1 (Offices, Conference rooms, Lobbies)	4372	SF	$ 7.0	$ 30,604	$ 6.0	$ 13	$ 56,836
Rubber Flooring - RT1 (Stair's Treads, Risers, Landings)	654	SF	$ 10.0	$ 6,540	$ 6.0	$ 16	$ 10,464
Ceramic Floor Tile - TL01 (Bathrooms)	263	SF	$ 14.0	$ 3,682	$ 8.0	$ 22	$ 5,786
WALL FINISHES							
TILE							
Ceramic Bath Tiles - TL01(at bath tiles assumed 4' h)	392	SF	$ 12.0	$ 4,704	$ 7	$ 19	$ 7,448
GYPSUM BOARD / PLASTER							
WALLS							
General Partitions	4451	SF	$ 4.0	$ 17,804	$ 17.0	$ 21	$ 93,471
Shaft Walls	1837	SF	$ 5.0	$ 9,185	$ 20.0	$ 25	$ 45,925
2hr Rated Partitions	8296	SF	$ 6.0	$ 49,776	$ 18.0	$ 24	$ 199,104
Install HM Frame - Single	9	EA			$ 250.0	$ 250	$ 2,250
Install HM Frame - Double	6	EA			$ 300.0	$ 300	$ 1,800

CEILING							
Drywall Ceiling	6043	SF	$ 4.0	$ 24,172	$ 20.0	$ 24	$ 145,032
PAINT							
WALLS							
Paint Drywall Partitions	14583	SF	$ 0.7	$ 10,208	$ 3.3	$ 4.00	$ 58,332
CEILING						$ -	
Paint Drywall Ceilings	6043	SF	$ 0.7	$ 4,230	$ 3.0	$ 3.70	$ 22,359
						$ -	
Paint Metal Railings	160	LF	$ 1.5	$ 240	$ 4.0	$ 6	$ 880
						Subtotal=	**$ 661,914**
DIVISION 10- SPECIALITIES							
						$ -	
TOILET ACCESSORIES						$ -	
FURNISH & INSTALL 36" L VERTICAL GRAB BAR	4	EA	$ 85.0	$ 340.0	$ 45	$ 130	$ 520
FURNISH & INSTALL 42" L HORIZONTAL GRAB BAR	4	EA	$ 85.0	$ 340.0	$ 45	$ 130	$ 520
FURNISH & INSTALL WALL MOUNTED MIRROR SIZE: 24" X 36"	4	EA	$ 150.0	$ 600.0	$ 85	$ 235	$ 940
FURNISH & INSTALL SOAP DISPENSER	4	EA	$ 135.0	$ 540.0	$ 65	$ 200	$ 800
FURNISH & INSTALL PAPER TOWEL DISPENSER	4	EA	$ 135.0	$ 540.0	$ 65	$ 200	$ 800
FURNISH & INSTALL SANITARY NAPKIN DISPENSER	4	EA	$ 65.0	$ 260.0	$ 20	$ 85	$ 340
FURNISH & INSTALL CLOTHING HOOK	4	EA	$ 65.0	$ 260.0	$ 35	$ 100	$ 400
						$ -	
						Subtotal=	**$ 4,320**
DIVISION 11- EQUIPMENT							

						$ -	
APPLIANCES						$ -	
Vending Machine	1	EA	$ 5,000.0	$ 5,000.0		$ 5,000	$ 5,000
						Subtotal=	**$ 5,000**
DIVISION 12- FURNISHINGS							
						$ -	
TABLES						$ -	
Table - TB1 (2'x2')	23	EA	$ 800.0	$ 18,400.0		$ 800	$ 18,400
Table - TB2 (2'-6"x 3'-6")	8	EA	$ 1,700.0	$ 13,600.0		$ 1,700	$ 13,600
Table - TB3 (3'x 7'-6")	1	EA	$ 4,000.0	$ 4,000.0		$ 4,000	$ 4,000
Office Desk - (2' x 4')	7	EA	$ 2,000.0	$ 14,000.0		$ 2,000	$ 14,000
SEATING						$ -	
Table Chairs - TB1, TB2, TB3	144	EA	$ 150.0	$ 21,600.0		$ 150	$ 21,600
Office Desk Chairs	7	EA	$ 300.0	$ 2,100.0		$ 300	$ 2,100
Sectional - L1 Lobby	1	EA	$ 3,000.0	$ 3,000.0		$ 3,000	$ 3,000
Couch - L1 Lobby	3	EA	$ 1,000.0	$ 3,000.0		$ 1,000	$ 3,000
MISCELLANEOUS							
Glass Markerboards	22	EA	$ 1,000.0	$ 22,000.0		$ 1,000	$ 22,000
						Subtotal=	**$ 101,700**
DIVISION 14- CONVEYING EQUIPMENT							
Schumacher elevator- MRL (5'-3" x 7'-3") 2500lb capacity	5	flts	65000	$ 325,000.0		$ 65,000	$ 325,000
Elevator premium finishes allowance	1	ALLW	10000	$ 10,000.0		$ 10,000	$ 10,000
						Subtotal=	**$ 335,000**
DIVISION 21 - FIRE PROTECTION							

Fire Protection - Allowance - (Fire Sprinklers, Fire Stopping)	6040	ALLW	5.5	$ 33,220.0		$ 80.0	$ 33,300
						Subtotal =	**$ 33,300**
DIVISION 22 - PLUMBING							
						$ -	
ALLOWANCE PROVIDED FOR PLUMBING PIPING, VALVES, BENTS, TRAPS, CLEAN OUTS, DRAINS, JOINTS ETC,	1	LS	$ 2,000.0	$ 2,000.0	$ 500.0	$ 2,500	$ 2,500
FURNISH & INSTALL AMERICAN STANDARD WATER CLOSET	4	EA	$ 4,500.0	$ 18,000.0	$ 500.0	$ 5,000	$ 20,000
FURNISH & INSTALL VANITY SINK	4	EA	$ 4,500.0	$ 18,000.0	$ 500.0	$ 5,000	$ 20,000
STORM DRAINAGE(Piping) - ALLOWANCE	6040	ALLW	$ 3.0	$ 18,120.0		$ 3	$ 18,120
GAS DISTRIBUTION (Piping) - ALLOWANCE	6040	ALLW	$ 1.5	$ 9,060.0		$ 2	$ 9,060
HOT WATER EQUIPMENT(Heater, Piping, etc.)	6040	ALLW	$ 1.5	$ 9,060.0		$ 2	$ 9,060
						Subtotal=	**$ 78,740**
DIVISION 23 - HVAC							
						$ -	
HVAC - Variable Air Volume System - Allowance (includes all associated cost for equipment, ducting, distribution and installation)	6040	ALLW	$ 60.0	$ 362,400		$ 60	$ 362,400
ALLOWANCE FOR MECHANICAL DUCTING INSULATION AREA =6040 SF	1	LS	$ 4,500.0	$ 4,500		$ 4,500	$ 4,500

						Subtotal=	**$ 366,900**
DIVISION 26 - ELECTRICAL							
						$ -	
Electrical - General Allowance (Area=6040 SF)	6040	ALLW	$ 35.0	$ 211,400.0		$ 35	$ 211,400
Tel/data (Conduit System)	6040	SF	$ 1.5	$ 9,060.0		$ 2	$ 9,060
Security System (Conduit System) - WPI Card Readers	6040	SF	$ 0.5	$ 3,020.0		$ 1	$ 3,020
						Subtotal=	**$ 223,480**
DIVISION 31 - EARTHWORK							
						$ -	
EXCAVATION						$ -	
Total Excavation	400.59	CY	$ -	$ -	$ 125.0	$ 125	$ 50,074
Testing, Treatment, and Disposal of Contaminated Soil (10%)	40.1	CY		$ -	$ 30.0	$ 30	$ 1,203
BACKFILLING						$ -	
TOTAL BACKFILLING FOR FOOTING	15.99	CY	$ -	$ -	$ 60.0	$ 60	$ 959
						Subtotal=	**$ -**
DIVISION 32 - EXTERIOR IMPROVEMENTS							
Concrete Paving 4"	6.82	CY	$ 144.0	$ 982.1		$ 144	$ 982
Subgrade 4"	6.82	CY	$ 50.0	$ 341.0		$ 50	$ 341
Tree Planting	2	EA	$ 10,000	$ 20,000.0	50	$ 10,050	$ 20,100
						Subtotal =	**$ 21,423**
DIVISION 33 - UTILITIES							
Relocation of Gas Pipelines	1	LS	$ 15,000			$ 15,000	$ 15,000
Trench Excavation for Storm Water	20	LF	$ 100.00			$ 100	$ 2,000

Trench Excavation for Electric and Telecom	20	LF	$ 50.00			$ 50	$ 1,000
Trench Excavation for City Water	20	LF	$ 100.00			$ 100	$ 2,000
Conduit - E&T	20	LF	$ 52.50			$ 53	$ 1,050
HDPE - 8" - Stormwater	20	LF	$ 22.00			$ 22	$ 440
SDR 35 Sewage Pipe - 8"	20	LF	$ 25.00			$ 25	$ 500
PVC- 4" - Fresh Water	20	LF	$ 13.00			$ 13	$ 260
Miscellaneous Pipe Connections	1	ALLW	$ 5,600			$ 5,600	$ 5,600
Trench Backfill	11.11	CY	$ 60.00			$ 60	$ 667
						Subtotal=	**$ 28,517**
						Subtotal=	**$ 3,532,789**
			SUBTOTAL				**$ 3,532,789**
			OVERHEADS & PROFIT			**35%**	**$ 1,236,476**
			TOTAL BASE BID				**$ 4,769,265**

Appendix D: Structural Analysis Calculations

1 The S.H.A.F.T Beam + Girder Calculations

Beams:

$W_u = 1.2 W_{DL} + 1.6 W_{LL}$

$W_u = [(1.2)(100)(5.5')] + [(1.6)(100)(5.5)]$

$W_u = 660 + 880 = 1540 \text{ lbs} = 1.54^k$

$M_u = \frac{(1.54)(26.5)^2}{8} = 135.18 \text{ kip-ft} : W14x26$

Check:

$W_u = W_u + (\text{self weight})$

$W_u = 1.54^k + \left(1.2 \cdot 26 \text{lbs} \cdot \frac{1}{1000}\right) = 1.57$

$M_u = \frac{(1.57^k)(26.5)^2}{8} = 137.82 \leq 151$ ✓

W14 x 26

$A = 7.69 \text{in} \quad d = 13.9 \quad t_w = 0.255 \quad t_f = 0.420 \quad k = 0.820 \quad b_f = 5.03$

$h = d - 2k$

$h = 13.9 - 2 \cdot 0.820$

$h = 12.26 \text{ in}$

$\frac{h}{t_w} < 3.76\sqrt{\frac{E}{F_y}}$

$\frac{12.26 \text{in}}{0.255 \text{in}} < 3.76\sqrt{\frac{29000}{50}}$

$48.08 < 90.55$

$\Sigma Q_n = 385^k$

$a = \frac{\Sigma Q_n}{0.85 f'_c b_f} \longrightarrow \frac{385^k}{0.85 \cdot 4 \cdot 26.5} = 4.27 \text{in}$

2 The S.H.A.F.T Beam + Girder Calculations

$Y1 = t - \frac{a}{2} \longrightarrow 5.25 - \frac{4.27}{2} = 3.115 in$

$M_n = A_s F_y \left(\frac{d}{2} + d - \frac{a}{2}\right) \longrightarrow M_n = (7.69)(50)\left(\frac{1.158}{2} + 1.158 - \frac{0.356}{2}\right)$

$M_n : 599 \cdot 0.9 = 539.49 \text{ kip-ft} = \phi M_n$

Anchor diameter: $3/8''$ $Y2 = 2 in$ $I_{LB} = 674$

Number of studs 6

Girder:

$W_u = [1.2 \cdot 100 \cdot 55] + [1.6 \cdot 100 \cdot 55]$

$W_u = 6600 + 8800 = 15400 = 15.4 \text{ K/ft}$

$M_u = \frac{(15.4)\left(\frac{26.5}{2}\right)^2}{8} = 337.96 \text{ kip-ft} \rightarrow W18 \times 50$

Check: $W_u = 15.4 \text{ K/ft} + \left(1.2 \cdot 50 \cdot \frac{1}{100}\right)$

$W_u = 15.46 \text{ K/ft}$

$M_u = \frac{(15.46)\left(\frac{26.5}{2}\right)^2}{8} = 339.27 \text{ K/ft} \leq 379$ ✓

3 The S.H.A.F.T. Beam + Girder Calculations

W18X50 $A = 14.7 in^2$ $d = 18.0 in$ $t_w = 0.355$ $t_f = 0.570$ $K = 0.972$

$b_f = 7.50$

$h = d - 2k$

$h = 18.0in - 2 \cdot 0.972 = 16.06in$

$$\frac{h}{t_w} < 3.36\sqrt{\frac{E}{F_y}} \longrightarrow \frac{16.06in}{0.355} < 3.76\sqrt{\frac{29000}{50}}$$

$45.24 < 90.55$ ✓

$\Sigma Q_n = 735$

$$a = \frac{\Sigma Q_n}{0.85 f'_c b_f} \longrightarrow \frac{735}{0.85 \cdot 4 \cdot 55} = 3.93in$$

$$M_n = (14.7)(50) \cdot \frac{\left(\frac{18.0}{2} + 18 - \frac{3.93}{2}\right)}{12}$$

$M_n = 1533.39$ ft-kips $\phi M_n = 1380.05$ ft-kips

$Y = 2in$ $I_{LB} = 1690$ $f'_c = 4ksi$ Concrete slab = 110 pcf

3/8" Studs, 8 total studs

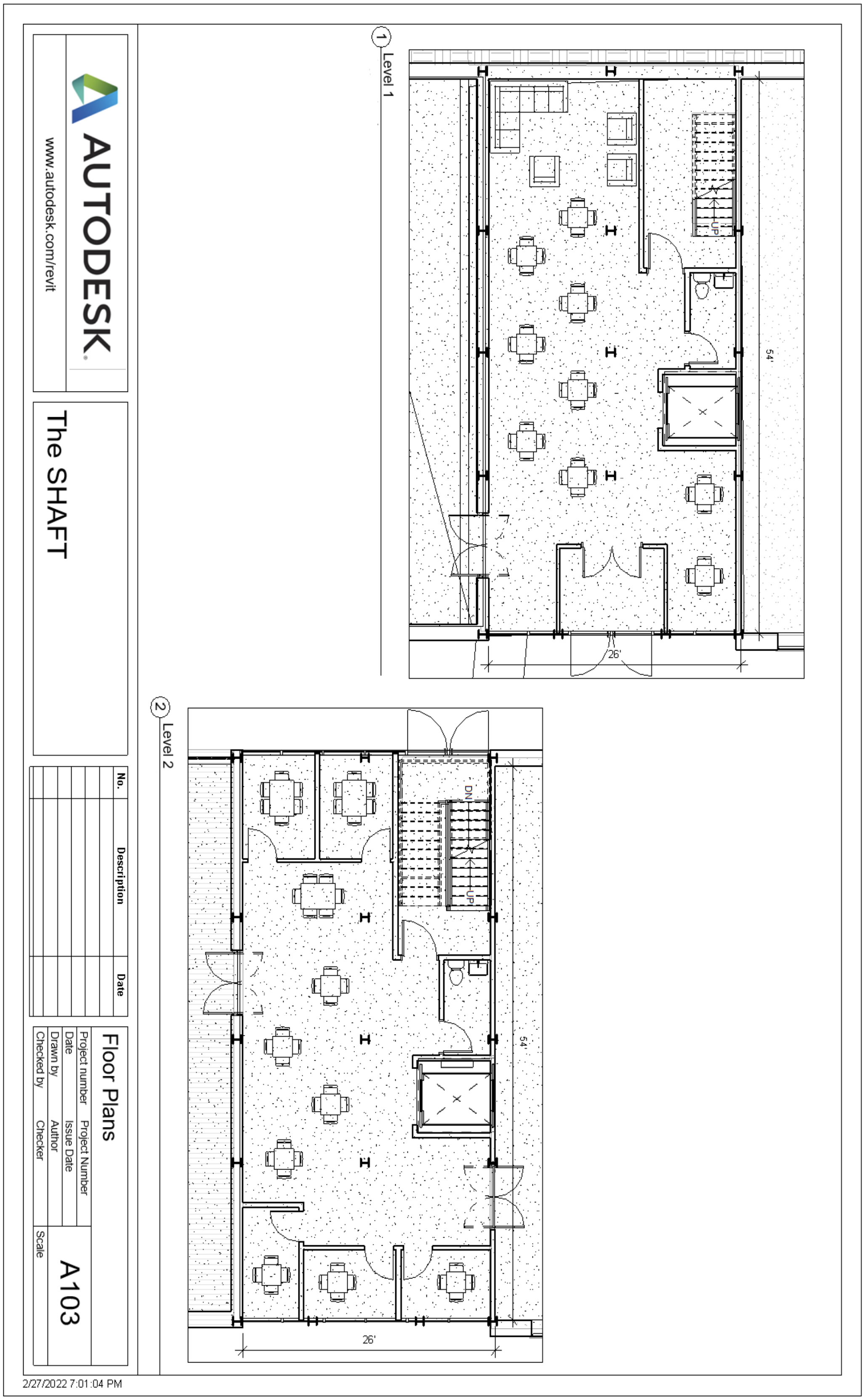
11 W14X26 beams and 2 W18X50 Girders

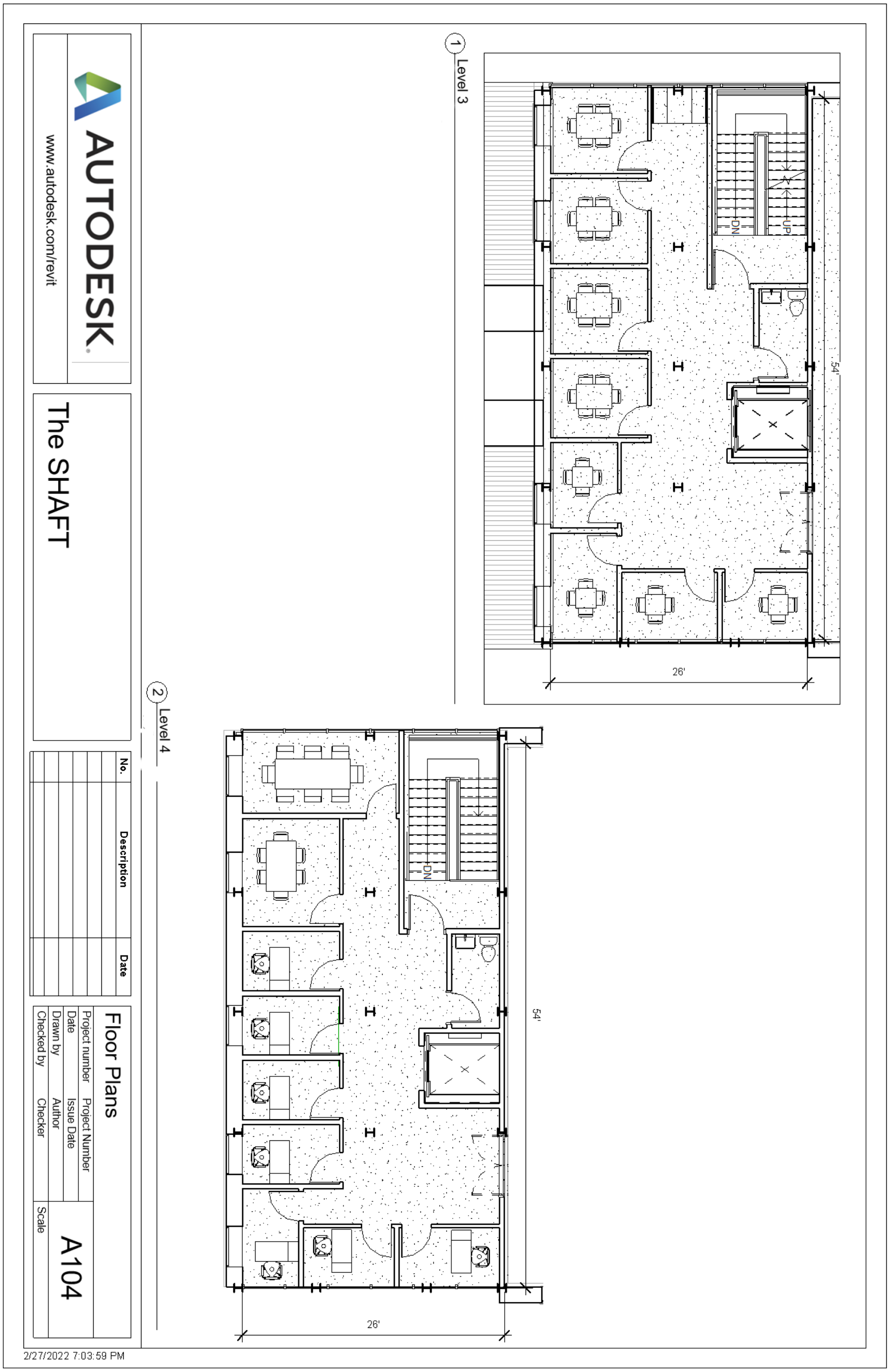
Beams: (11)(26.5')(26lbs) = 3.79 tons

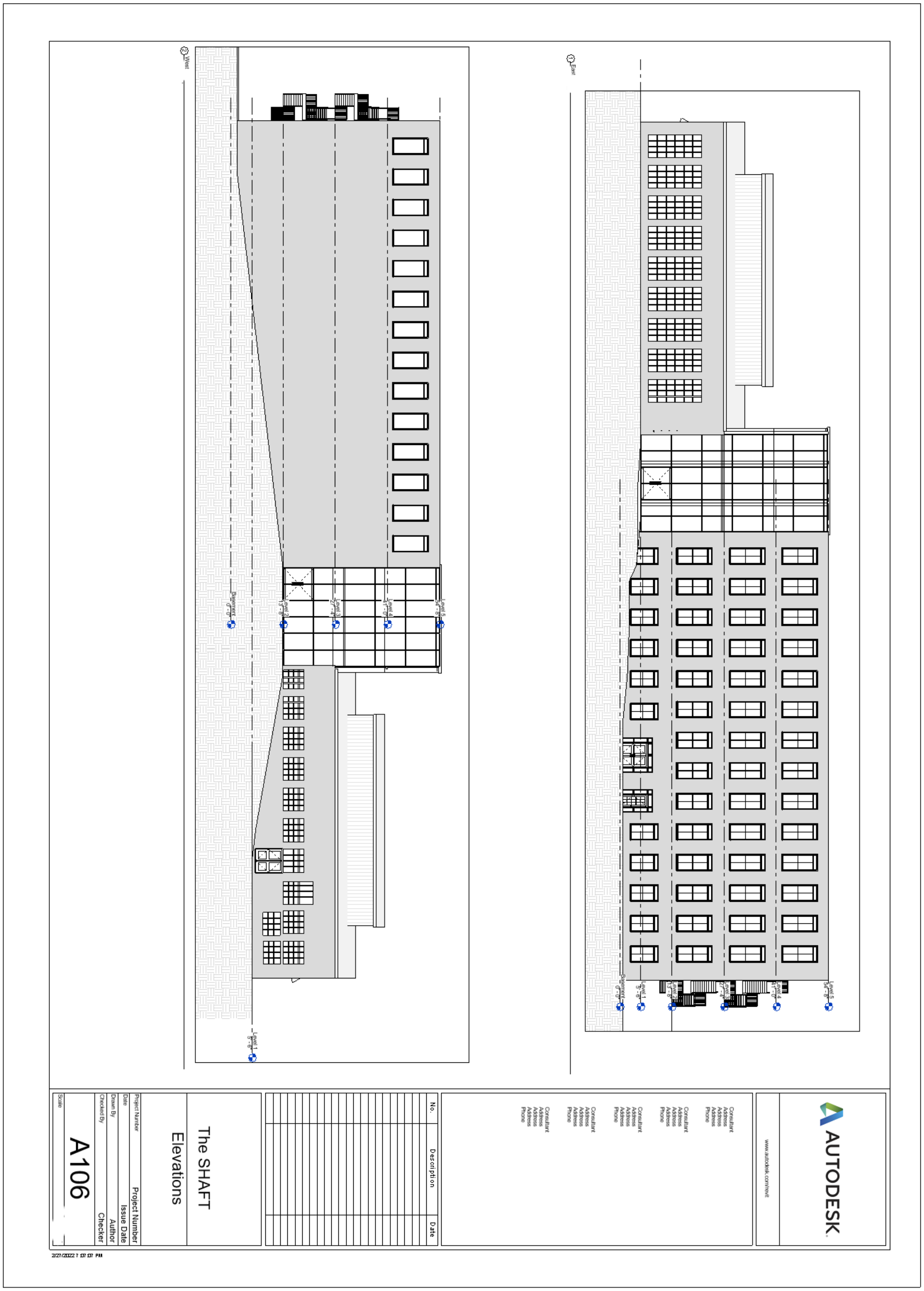
Girders: (2)(55)(50) = 2.75 tons

6.54 tons x4 floors = 26.16 tons

Appendix E: Drawing Sets for the S.H.A.F.T



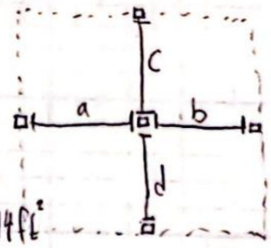

54'
UP
DN
26'
1 Level 3
54'
DN
26'
2 Level 4
AUTODESK.
www.autodesk.com/revit
The SHAFT
No.
Description
Date
Floor Plans
Project number Project Number
Date Issue Date
Drawn by Author
Checked by Checker
A104
Scale
2/27/2022 7:03:59 PM


AUTODESK.
www.autodesk.com/revit
No.
Description
Date
The SHAFT
Elevations
Project Number
Issue Date
Author
Checker
A106

Appendix F: Column Loading Calculations

The Shaft Column Calculations example

Tributary Area: Column 1



$$A = \frac{(a+b)(c+d)}{4}$$

$$A = \frac{(15.5')(13.125')}{4} = 51.344\,ft^2$$

HSS: 9" x 9" x 1/4"

Column height = 25 · 29.23 psf = 730.75 lbs

DL = 730.75 + (51.344)(5) + (51.344)(55 psf) + (51.344)(10 psf) = 3811.39 lbs = 3.81 kips

Live Load:

Stairs = 100 psf (51.344)(100 psf) + (0.7)(1.1)(55 psf)(51.344)

Live Load = 7308.82 lbs = 7.31 kips

Snow Load = $0.055^k \cdot 51.344 = 2.82^k$

Total Load = 1.2DL + 1.6LL + 0.5SL

= (1.2 · 3.81) + (1.6 · 7.31) + (0.5 · 2.82)

= 17.678 kips on column 1

for all floors acting on column = 50.216 kips