Project ID: GFS 1701

The Role of BIM in a Collaborative Approach for Design and Construction at the Foisie Innovation Studio

Submitted to the Faculty of the
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree of Bachelor of Science
In Civil Engineering by:

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March 3, 2017

Abstract

The owner, designer and construction manager involved in the development of the Foisie Innovation Studio being built on the WPI campus are conducting a well-coordinated collaborative process during the design and early parts of construction to incorporate the views and needs of different individuals and groups who are related to the many aspects of this facility. The authors attended design and construction meetings, reviewed project documentation and conducted interviews to document and analyze this collaborative approach and proposed an approach to integrate design lifecycle information using Building Information Modeling (BIM).

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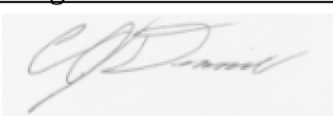
The signatures below indicate the acceptance of the above



Capstone Design Statement

This project proposes the design of a Building Information Modeling (BIM) based process to assist a collaborative design and construction approach that integrates design lifecycle information. The approach is partially implemented based on the observations that took place during the design and early construction phases of the WPI Foisie Innovation Studio. The proposed process takes into account specific design constraints including economic, sustainability, and social.

Social

This is a highly interactive process involving many individuals and groups from the owner, designer and construction management organizations. For this purpose, flow charts were designed to document and display how the collaborative design process works. These charts were created by identifying design items that required lengthy and multidisciplinary collaboration. The major players were defined in the project by company and then broken down further into specific people involved. The movement of information from stakeholder to stakeholder drove the design of the charts. These illustrations capture the social collaborative nature that was used to ensure for a great project and sufficient lifecycle of the building.

Economic

The report investigates the cost and schedule of the construction of the Foisie Innovation Studio to understand the efficiency of the project and the impact on the WPI community. The development of the owner's budget and the impact of key design decisions were tracked over time until the final Guaranteed Maximum Price (GMP) was agreed upon between owner and subcontractor. The project schedule was also followed as the design and early phases of construction took place over the period of observation to determine areas where time was lost or gained and how this affected the project. Changes resulting in losses or gains of time and in the budget are tracked to determine their overall effect. Value engineering was also examined with the changes that were made to portray how the design and CM teams worked to reduce costs.

Sustainability

As a final deliverable, this report proposes a design for a better collaborative approach with the use of BIM technologies to further enhance the lifecycle of the building. This design takes into consideration the use of current BIM practices and suggests new actions to be taken in the future. This design suggests ways that WPI can be more efficiently involved in construction projects as well as helping to create better models and data for lifecycle of a new building on campus. The sustainability aspect focuses on the extension of data created during design and construction for future operation of the building by the facilities management staff, thus insuring a more efficient long lifecycle management of WPI buildings. A BIM Execution Plan that could be used in the future by WPI is attached to this report as a supplemental document.

Constructability

The design of the Foisie Innovation Studio was completed by Gensler Architects. The building contract for this project was construction management at risk with design pre-construction services in order to incorporate constructability knowledge into the design decisions early in the project. Shawmut Design and Construction took part in design discussion between WPI and Gensler to advise the development of the design from the builder's point of view and to assist in the control of the budget during the design process. Several collaborations were used to improve the design for a timely capture of the views of different stakeholders and for the best interest of the WPI community. As a result many changes took place before the actual construction started helping in attaining the established budget and deadline for the completion of the project.

Ethics

All parties involved in the development of the project maintained the highest level of business ethics. Respect, professionalism and transparency were consistent throughout the project. Private information relating to the project was shared with the WPI project team. Information stored in the construction management firm's Procore online information system such as construction drawings, and contractor estimates were shared with the team. The project team abided by the confidentiality agreement signed at the beginning of the project.

Safety

Throughout the duration of the project (as current as this report), the job site did not witness any accidents or injuries. During every owners meeting, precautionary measures were discussed in order to maintain job site safety as an item in the meeting minutes. Only authorized personnel and activities were allowed on site and required the use of proper personal protective equipment (PPEs). Time was also taken to assure all students on campus were under no risk of injury. In order to achieve this, the site was properly secured with temporary fencing, and crane usage was approved to ensure suspended material did not extend beyond the fence boundary. During this period the safety staff from Shawmut and WPI met often to coordinate safety procedures applicable to the job site and to WPI campus at large.

Professional Licensure Statement

Obtaining a license for design work in construction allows for the government and the industry to hold those in charge responsible for their professional work. Licensure also allows for design work to be held to the highest standards set forth by civil engineering standards agencies. It is important for licensed engineers to act and work in a respectable, ethical, and professional manner because their designs may impact a large population.

The first step towards obtaining a Professional Engineering License is to first pass the Fundamentals of Engineering (FE) exam. Passing this exam allows the individual to be an engineering in training, where they are to spend five years working under an engineer with the Professional Engineering License. After the five years, a compilation of the trainee's work is put together and presented before a board of well standing professional engineers. Upon their approval and the passing of the Professional Engineering (PE) exam, the engineer in training receives their Professional Engineering License. Having a degree from an accredited civil engineering program is highly recommended when applying for the FE and PE. WPI offers an accredited degree which is very useful in obtaining these licenses. Having an accredited degree in civil engineering is required in order to take and receive a PE license, so WPI's undergraduate and graduate programs are a great institution to be able to have the knowledge necessary to obtain these licenses.

There are other types of licenses and certifications as well in the construction industry. One of these is a construction supervisor's license. These licenses must be renewed each year in order to keep them. Another form of license that can be obtained is the OSHA 10 or OSHA 30.

These tests are mandatory for anyone in the construction industry to ensure that they remain up to date with current safety regulations.

The licenses and programs are important for the construction industry at large to ensure that capable, ethical, and professional individuals are in charge of all building projects, giving everyone involved a sense of certainty and safety.

Acknowledgments

We would like to thank all of those individuals who were involved in the Foisie Innovation Studio design and construction. Without them this project would not have been possible. We would like to thank WPI and several of the faculty that allowed us access to various files and programs for further insight into our project. They were also kind and punctual with emails as well as with interviews. We would like to thank Shawmut Design and Construction for allowing access to their Procore information system and files as well as allowing us to attend weekly owner's construction meetings at their site office. Finally, we would like to thank Gensler Architects and KVA Building Industry Consultants for also giving us much insight into the collaboration and construction process of the new Foisie Innovation Studio on campus and granting us the privilege of observing their professional work and knowledge in action.

Special thanks goes to:
Gensler Architects
- **Ken Fisher**
- **Keller Roughton**

KVA Building Industry Consultants
- **Jeff Lussier**

Shawmut Design and Construction
- **Mohamed Aboulezz**
- **Ruth Ducharme**
- **Nathan Gauthier**
- **Josiah Herbert**
- **Michael Kearns**
- **Matt Lafond**
- **Toni Papadopoulos**

Worcester Polytechnic Institute
- **Jim Bedard**
- **Phillip Clay**
- **Fred DiMauro**
- **Alison Duffy**
- **Amy Beth Laythe**
- **Guillermo Salazar**
- **Jeffrey Solomon**

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1.0 Introduction

Alumni Gym has been seen by many generations of WPI students since its construction in 1915. The building was nested between Harrington Auditorium and Higgins Labs at the northeast region of the WPI quadrangle. Since the construction of the new Sports and Recreation Center in 2011, Alumni Gym became vacant. WPI had commissioned for a study in 2013 to repurpose the old Alumni Gym for academic space use dedicated to promote innovation at WPI, however the estimated cost was to be over $18 million. In the eyes of WPI and Assistant Vice President of Facilities Alfred DiMauro, "modernizing the building was impractical" because "it would create a financial hardship and an inefficient use of the building." (Collins et. al. 2016) In October 2014, WPI Alumni launched a fundraising project to help fund the creation of the Foisie Innovation Studio. (WPI 2016) There was also a challenge grant created in January of 2015 by the George I. Alden Trust for $3 million that would only be fulfilled if the school raised $9 million in eighteen months. (WPI 2016) In total, $18 million was raised by about 1,550 donors ranging from first time donors to some that have not donated in several years. (WPI 2016)

After many considerations to this investment and fundraising, WPI announced that Alumni Gym would be demolished and make way for the brand new Foisie Innovation Studio and Messenger Residence Hall after graduation in May of 2016. (Collins et. al. 2016)This new landmark building that will be part of the WPI campus is a $49 million, 78,000 square foot facility that was designed by Gensler and constructed by Shawmut Design and Construction. The Messenger Residence Hall will feature space for one hundred forty students. (WPI 2016).

The owner, designer and construction manager involved in the development of the Foisie Innovation Studio being built on the WPI campus are conducting a well-coordinated collaborative process during the design and early parts of construction to incorporate the views and needs of different individuals and groups who are related to the many aspects of this facility.

This Major Qualifying Project (MQP) investigates the collaborative approach for the lifecycle design of the Foisie Innovation Studio. The report begins with a literature review of current building lifecycle designs and different construction contract delivery methods. This literature review shows how old practices of design-bid-build have evolved and construction practices are now becoming more collaborative among the various project team members. The review takes an in depth look at integrated project delivery and how this is affecting projects.

The report also gives an in depth analysis of the current standing of the Foisie Innovation Studio. This section describes the demolition phase of Alumni Gym and the features that will be a part of the new building. Other topics include the various team members including the owner team, design team, and construction management team. A look into the cost and schedule of the construction is also performed. The final part of the analysis of the current construction is how BIM is used. The use of BIM is linked to how it is used by the design team, the construction management team, and by facilities management.

After the analysis of the current construction status of the building, an in depth analysis of the collaboration amongst various members of the project is performed. This section demonstrates the power of a GMP contract and how the construction management at risk with a GMP project delivery system is an effective strategy for fast-tracking the development of the project. This section also demonstrates how the collaboration among the project members works and describes how issues and questions that emerge during this process are solved throughout the project. Several specific issues are tracked throughout their development and flowcharts were designed to display the effectiveness of various collaborations.

The final section of this report discusses how a greater implementation of BIM would have improved the project and collaboration even more. A design is proposed on how and where BIM technologies could have been implemented or where BIM technologies could have been used in a higher capacity. The final design details which BIM technologies should be targeted for future projects and how they will increase collaboration and the lifecycle of a new building.

2.0 Collaborative Lifecycle Design

Collaboration in design and construction is an increasingly used approach to reduce cost, time, risk, and improve the quality of the project delivered to the owner. Traditionally, projects are separated into many independent phases such as planning, design, construction, and maintenance. Each stage of the construction process is usually implemented with little to no communication and interactions with participants of other steps in the procedure. This lack of communication tends to lead to a lot of problems. For example, if the designer and construction manager do not communicate during the design process, then a significant amount of rework may be required during the construction process due to poor constructability in the design. By taking a collaborative design approach, and increasing the level of communication across project phases, issues can be identified earlier, thus reducing unforeseen costs and schedule delays.

2.1 Collaborative Planning, Design, Construction, Facilities Management

Collaborative Design among the owner and the project team comprised by the builder and designer have one shared goal. They are to jointly define and perform their scope of work on the project to fully satisfy the objectives of the owner. Integrating project phases from beginning to end yields the term “project lifecycle” (Watt 2013). In the planning process, the project objective or need is identified. The owner consults various stakeholders in order to determine how the project can fulfil the needs of its users. Moving forward into the design phase, the owner works with the architect who is typically the lead designer in a building project to establish performance requirements for the building and to produce a design that meets the specified requirements. A management consultant is often present throughout this process to assist the owner. A schedule must be prepared, and costs need to be estimated by the construction manager. Once these tasks are complete, the project is ready to move into the construction phase. Here, the construction manager takes the lead in the project. They are responsible for monitoring and recording any variance of the built facility from the original plans in a professional format. Additionally, they provide continuous status reports to the owner in regard to the buildings variance from the schedule and budget. Upon completion of the project, the building is commissioned and handed over to the owner. At this point, the project enters its fourth and final stage of operations and maintenance and overall facility management.

2.2 Design to Cost (DTC)

Cost management is a frequent topic of conversation throughout a construction project. All members involved on the project collaborate to keep the project within the budget determined by the owner. A commonly used concept to assist in cost management is Design to Cost (DTC). It is a systematic approach to controlling the costs of product development and manufacturing during the design stage. In the early stages of decision making, costs are designed “into the product” to help guide the budget into a tier that is satisfying to the client. Essentially, DTC considers cost as a design parameter in the development stage of the project (Hiller, 2013). In some cases during the development stage, there is no system that can meet the owner’s request. Under this circumstance, collaboration among project teams is in the highest demand.

2.3 Traditional Practices of Design-Bid-Build

The traditional Project Delivery System (PDS) to the mobilization of a construction project is Design–Bid–Build (DBB). As the name suggests, there are three main phases in this approach. Within every phase, there are multiple steps taken to thoroughly complete the project. The need for a good or service is determined, and project planning begins in order to determine exactly how to satisfy the owner's requirements. This project planning in the design phase is known as the "schematic design phase" (SD). The architect and the architect's consulting engineers take the lead in carrying out this first step of the design phase. Once the schematic design documents are completed, and approved by the owner of the project, the architects begin on the second step to the design process known as the "design development" (DD) stage (Brookwood, 2011). During the DD stage, the architect adds to the SD documents and begins to write the specifications for the project at the owner's discretion. The DD documents are then released for bid to potential construction managers or general contractors. The first round of the bidding process runs in tandem with the development of the "Construction Documents" (CD). A second round of bidding is done by possible construction managers once the CDs are completed. Once the second round of bidding is completed, the owner ultimately hires a construction manager for the project. At this point the project is ready to start the third and final stage of the process, known as the building phase. During the building process, the construction manager hires many subcontractors that specialize in various trades to complete the project at a quality satisfying to the owner, on time, and within budget. Phases are separated and there is no opportunity for collaboration.

2.4 Integrated Practice: CM-Precon, DB, IPD

Breaking away from the DBB approach is the concept of integrated practices throughout the construction project. Contrary to the DBB, each project team involved would communicate with one another to a varying degree, and be included in more than just their individual phase of construction. There are two approaches that adopt this concept that are gaining popularity in the construction industry. The most popular of these is the Design – Build (DB) approach where the designer and construction manager are both hired as a single entity by the owner to deliver the design and construction of the facility. Under this PDS, the construction specialists (designer and builder) are hired at an early stage in the projects once the design has started thus, enabling them to be in tune with what the architect and owner are discussing. This minimizes the possibility of communication breakdowns and unfeasible designs later in the project's development. A fully integrated PDS is the Integrated Project Delivery (IPD), which takes the Design-Build process to a higher level of integration. All entities involved on the project share risk and reward on the project through a multiparty contract agreement, thus incentivizing all teams to work together with the highest level of cooperation and collaboration.

2.4.1 IPD: Owner, Designer, CM

The Integrated Project Delivery's main goal is to create a team effort integrating owner, architects, construction manager, and subcontractors. Contrary to other project efforts, the IPD creates a unique bond at the beginning of the planning stage, so all companies have a shared interest in the success of the project. The IPD approach is especially attractive to the owner. They no longer need to play referee between the architect and construction manager, when there is an unexpected cost that one of them needs to be covered. Additionally, the construction manager and architect are completely transparent throughout the process. There are no hidden cost agendas that will be revealed later. Professional associations like American Institute of Architects (AIA) and Associated General Contractors of America (AGC) are creating standards and guidelines to be used in the Integrated Project Delivery process (Integrated Project Delivery Collaboration).

2.4.2 IPD: Early Design Input (Design Assist)

Design Assist is a collaborative approach assistive that calls for the hiring of a building contractor to provide construction knowledge input during the design process with the owner, architect, and engineer. At first glance, the approach appears identical to design – build, but there is one major legal difference between the two. MEP contractors are responsible and liable in a design – build project where-as the engineer and architect are liable in a design-assist project (Murphy, 2013). Design-assist is an attractive concept to the building owner because the MEP contractor can help ensure the project runs smoothly through the design and development phase, and the owner gets the most "bang for their buck" in the project. This process is frequently adopted for the design of the mechanical, electrical, and plumbing (MEP) scopes of work.

2.4.3 IPD: BIM

After the design process, IPD calls for the use of Building Information Modeling (BIM). BIM is a collaborative enabling technology since it can be accessed by all project members at any time. Programs such as Revit, Autocad Civil 3D, BIM 360, Navisworks, and many others allow for multiple people to access information as well as making and tracking changes. The architect is the first party to work on the model. Once construction is mobilized, the construction manager works with the architect's model, and makes necessary adjustments to reflect the as-builts. In addition to making these changes, the construction manager also receives models from subcontractors and works with them to combine the models to check for hard clashes and violations of building codes. Upon completion of the project, the owner receives the model for facility and maintenance purposes. Parties join forces in this process to provide the owner an accurate depiction of their building.

2.4.4 IPD: WPI's Approach

WPI is taking the construction manager at risk project delivery to construct the Foisie Innovation Studio on campus. Shawmut Design and Construction is the construction manager on the job working in tandem with Gensler Architects. The two companies first began working with one another very early in the project's lifecycle. Shawmut Design and Construction was actually hired much earlier than Gensler because they provided many beneficial pre-construction services for WPI. The Foisie project is not an official IPD contract where all parties are contractually bound to work in full collaboration and share success and liability. However, there are many areas of the project where the project was approached in an IPD-like fashion. Design assist was one IPD concept that has been used on the Foisie project. Additionally, there were many times throughout the project where multiple project teams worked in tandem with one another to come to a design decision that satisfied the objectives of the stakeholders involved in specific issues requiring multiple views. A collaborative IPD-like fashion approach was most frequently observed when uncertainties were expressed by the building owner involving multiple parties' objectives.

3.0 Foisie Innovation Studio

Figure 1 Rendering of the Foisie Innovation Studio

Plans for design and construction of the Foisie Innovation Studio took form in the past few years and WPI Alumni launched a fundraising project to help fund the effort (WPI 2016). $18 million was raised in order to fund the cost of a building that would ultimately take place of the Alumni Gym on campus. Final plans designed by Gensler call for a five story, 78,000 square foot structure that will cost Shawmut Design and Construction $49 million to deliver to WPI. (WPI, 2016) The building will serve a variety of purposes on campus and a rendering produced by the designer of the completed building is shown in Figure 1. The first floor will feature a robotics lab, maker space, high-tech classrooms for Great Problems Seminars – courses that introduce first-year students to team-based projects focused on real-world problems as well as a cafe (WPI 2016). The second floor will have several offices as well as active learning classrooms. The three floors above the innovation center will serve as a residential hall for first year students.

3.1 Alumni Gym Repurposing

The site where the Foisie Innovation Studio will be standing in the fall of 2018 used to be the site for Alumni Gym which was built in 1915. Back in 2014, there were several professional studies and MQP groups that worked on redesigning and renovating the existing building such as the “Proposed Design for the WPI Foisie Innovation Studio” in March of 2016 (WPI, 2016). In fact, an architectural firm and a construction manager firm were hired to develop the design according to WPI new objectives and financial constraints for the building. Many of those in the

WPI community wanted to save the building because of its age and legacy. Figure 2 shows the old Alumni Gym before demolition. The re-purposed design of the space however, had many constraints in terms of the space an estimated cost and WPI decided not to proceed with this solution and demolish the building. Therefore, an entirely new building was designed.

Figure 2 Alumni Gym Before Demolition

According to the school news back in 2014, "the 34,255 square foot floor plan has four levels dedicated to student project work, with mechanical and storage facilities on the fifth floor." (Killough-Miller 2014) There were several essential aspects from the repurposing that were preserved in the design of the new Fosie Innovation Studio. Some of the key features originally included in the repurposing were a 1,400 square foot atrium with interactive digital displays, a new robotics laboratory, maker spaces, new classrooms for Global Projects Seminar (GPS) and business classes, and offices for several disciplines. (Killough-Miller 2014) The total duration and cost of the new project was estimated to take from May of 2016 till the fall of 2018 at a cost of construction for the building of $38 million.

3.2 Alumni Gym Demolition

Demolition of Alumni Gym began shortly after the graduation of the class of 2016 in May 2016. According to the preliminary master schedule for Shawmut, demolition was to be completed by September 19th, 2016. The demolition was done by JDC Demolition (60 Gerard St, Boston, MA) and by the final week of September, JDC had only one machine left cleaning up for the site work to be done next. The demolition consisted of bringing the building down in sections. Abatement had to be done on hazardous materials, like asbestos, prior to demolition of the building. (Jeff Lussier, 2016) This work started in February of 2016 and was completed before the building started to come down in late May 2016. Estimates for the costs of demolition, were conservative on the abatement amounts because there were some areas of the building that could not be seen and measured (Jeff Lussier, 2016) There was a $21,040 abatement reconciliation because of the extra work that had to be done for areas that were blind before demolition. Figure 3 shows Alumni Gym during demolition in August of 2016.

Figure 3 Alumni Gym During Demolition, August 2016

The demolition started by placing a fence around the building, gutting out the entire Alumni gym, and removing the glass windows. The building was taken down in sections because of the close proximity to other buildings like Harrington Auditorium, Higgins Labs, and the Rubin Campus Center. Once the building was leveled, JDC Demolition worked on separating the different materials from the debris. Metal, concrete, and masonry were all divided into separate piles and trucked out to their specific dumping or recycling sites.

3.3 New Building

The owner, designer and construction manager involved in the development of the Foisie Innovation Studio being built on the WPI campus are conducting a well-coordinated collaborative process during the design and early parts of construction to incorporate the views and needs of different individuals and groups who are related to the many aspects of this facility. The project is broken up into the various teams which include the owner team, design team, and the construction manager team. This section investigates each of these project teams, the cost and schedule of the construction, and the use of BIM technologies in the project.

3.3.1 Contractual Organizational Structure

WPI chose the Construction Management at Risk contractual approach to deliver this project. This allows for early involvement of the builder while the design is in its early stage. In selecting the architect and the construction manager for this project, WPI was looking to promote a collaborative attitude among the members of the project team. As an owner, WPI has learned from the projects built over the last 15 years that involving the different institutional groups with a stake in the new building early in the design greatly improves the lifecycle functional and economic aspects of the facility. Therefore, the designer and construction manager must collaborate closely with WPI. The main players in the project, as are typical in most construction projects, are the owner/consultant, architect, and construction manager. For the Foisie project the owner is Worcester Polytechnic Institute who is using the services of KVAssociates as their owner's representative. The main architect is Gensler Architects with Nitsch Engineering, LeMessurier and ARUP as major design consultants. Shawmut Design and Construction is the construction manager for the project.

These groups are working together in a collaborative approach that builds upon techniques from the design-build method, integrated project delivery, and a construction manager with a guaranteed maximum price contract (GMP). The blending of these approaches is to minimize the risk among the project members as well as allow for easy communication and problem solving.

The design-build approach allows for construction to begin while designing is still taking place. The 100% construction documents were developed and approved while designs for items such as furniture and classroom size were still not completed. This allowed to fast-track the schedule leading to a shorter project duration. Some design decisions can be overlapped, for example, table sizes and shapes for the classroom do not need to be finalized when site work and foundations are being constructed. The integrated project delivery system touches upon the collaborative approach as the different teams do several activities together. These include but are not limited to, weekly meetings, presentations to the WPI Board of Trustees, safety meetings, meetings with different WPI stakeholders, and much more. The GMP contract allows for risk to be transferred from WPI to the construction manager "locking in" a final guaranteed maximum price that the owner will pay once the project is satisfactorily completed. Contingencies are placed into the budget and savings accrued from a final cost lower than the GMP benefit the owner. Any cost overruns over the GMP become the financial responsibility of the construction manager.

3.3.2 Owner Team

The owner team consists of Worcester Polytechnic Institute and WPI's project manager consultant in KVAssociates. There are several people from WPI that are directly involved in the project. Those that are mostly involved and attend weekly construction meetings are listed in Table 1 below.

Table 1 Owner Team Personnel

WPI Team Member	Title
Jeffrey Solomon	Executive VP/CFO
Phillip Clay	VP for Student Affairs
Fred DiMauro	Assistant VP for Facilities
Jim Bedard	Director of Construction Services
Alison Duffy	Assoc. Dir., Public Relations, Marketing, and Communications
Amy Beth Laythe	Sr. Assoc. Director of Res. Ops.

These are the key team members who have direct input on designs and attend most of the meetings that are a part of the Foisie Innovation Studio construction project. Other WPI representatives on specific components of the building also participate as needed. There have been several meetings among all of the members of the Foisie project. Some of these meetings have included weekly construction meetings, curtain wall design, facilities management, and more. The complete list and a greater detail of these meetings are described in Appendix C. Jeff Solomon is in charge of managing with the consultant on the budget and overall costs regarding the project. He has helped work on the GMP that was created and is also the direct link to President Leshin for providing information for the project. Fred DiMauro and Jim Bedard are involved with the construction and future operation and maintenance of the project. They usually will keep track of permits, meet with inspectors, and provide input on design details. They also coordinate with other WPI stakeholders involved in this process. Other WPI team members are listed in Table 2.

Table 2 Owner Team Secondary Personnel

WPI Team Member	Title
Bill Spratt	Director of Facilities Operations
Elizabeth Tomaszewski	Assoc. Director od Sustainability
Roger Griffin	Assoc. Dir., Mechanical Services
Guillermo Salazar	Civil Engineering Professor
Nancy Burnham	Physics Professor
Kris Wobbe	GPS Professor

These WPI group members usually do not attend the weekly owner meetings but they are available when called upon or at special meetings dedicated to discuss specific issues of the design. For example, Bill Spratt and Liz Tomaszewski were involved in lengthy discussions about how the record documents and as-builts from the project would be transferred to WPI facilities staff. The physics and Global Project Seminar (GPS) professors weighed in heavily discussing classroom density and furniture selection because they are going to be using the classrooms that will be featured in Foisie. More information on these topics can be seen in section 4.

The owner team is also comprised of WPI's representative which is KVAssociates from Boston. The individual that serves as WPI's representative and has also been their representative on past construction projects is Jeff Lussier. Jeff has vast experience in this capacity and his job is to ensure that design and construction runs smoothly and meets the desired budget and schedule that is agreed upon by the team members. Jeff also serves as a mediator when there are questions or issues that arise within in the project.

3.3.3 Designer Team

The design team is mainly compromised of the lead architect Gensler, and by the main design consultants ARUP and Nitsch Engineering. Gensler is represented at all of the design, pre-construction, and construction meetings for the Foisie Innovation Studio and the other companies are sometimes phoned in and always kept up to date. The main representatives at the site for Gensler are Ken Fisher and Keller Roughton, who participate in the weekly construction meetings as well as planning board meetings and meetings within WPI. Gensler was brought on board in late 2015 and is responsible for the architectural design of the Foisie Innovation Studio. They generated the construction documents and during construction, review and approve submittals and shop drawings from various subcontractors as well as keeping the 3D model of the building up to date. Gensler also coordinates with WPI and the construction manager on the creation of several mockups to simulate different parts of the building. One example is a large feature wall that will be placed in the lobby of the first floor. Gensler has created different options with different price points that allows WPI to choose their preferred design. Gensler is also in charge of making changes to documentation and models if the owners or construction manager see the need for a major change.

3.3.4 Construction Management Team

Shawmut Design and Construction is the construction manager that was hired for the demolition of Alumni Gym and the construction of the new Foisie Innovation Studio. Shawmut takes the role of managing the construction project from the trade subcontractors down to their final bids involved. They participated at all pre-construction meetings and during construction they are in charge of running the weekly construction meetings, interviewing and hiring subcontractors, generating estimates and requisitions, and ensuring safety on the job site. The list of direct Shawmut personnel can be seen in Table 3.

Table 3 Construction Manager Team Personnel

Shawmut Team Member	Title
Michael Kearns	Project Executive
Josiah Herbert	Senior Project Manager
Ruth Ducharme	Assistant Project Manager
Toni Papadopoulos	Assistant Project Manager
Matt Lafond	Superintendent
Ryan Zraunig	Assistant Superintendent

The project manager, Josiah Herbert, and his assistant project managers, Ruth Ducharme, and Toni Papadopoulos, are in charge of the construction meetings and day to day activities concerning the project. They work on identifying subcontractors, interviewing them, identifying the best candidates, discussing options with the owner and finally selecting the best candidate for the job. They are in charge of paying subcontractors as well as for creating the requisitions for payment from WPI. The Shawmut project managers are also responsible for preparing RFI's and submittals between various parties that are involved in the project.

The superintendents, Matt Lafond and Ryan Zraunig, are in charge of the day to day activities on site. They are responsible for the subcontractors that are working on site. They plan for the subs to mobilize on site, what work is to be completed each day, and demobilization. The superintendents are also in charge of keeping track of the construction schedule and ensuring that everything remains on track as according to the master schedule. The superintendents deal with issues that arise on site such as a water main break. They are also in charge of safety on site since there are many hazards including machinery, falls, materials, and more. Everyone on site is required to uphold OSHA standards by wearing a hard hat, safety glasses, safety vests, and other PPE's.

3.4 Cost

As of 11/9/16 it was brought to the attention exactly how far behind the project was. It was estimated that the project was about two months behind schedule for two reasons. One reason was because the Massachusetts Historical Society delayed the initiation of the project for about a month discussing historical-related items of the old Alumni Gym building such as the removal of the grotesques from the top of the building before demolition. The second reason is that the complexity of the constructability of the project has also set the project back another month. The way the project team is going to try to recover this lost time to accelerate certain processes including collaborative and active design resolutions during construction, commissioning, punch lists, and building loading.

One important scheduling issue that was monitored during the development of this study was the submittal of structural steel. Steel has a turnaround of five weeks from approval to delivery to the site. The steel was most likely shipped from Canada which is important to note because Canadian steel mills close for two weeks for Christmas. Shawmut has a target date of November 22nd to approve the steel to ensure that five weeks does not extend to seven weeks.

The November 2016 requisition for the Foisie Innovation Studio gives a good look at how construction is advancing. There are currently ten items from the contract that are in progress and the project is at 7% complete in terms of the scheduled value. The amount of $2,522,507.71 has been spent out of the total of $37,685,669.00. As of the November 2016 requisition there are three out of the ten items in progress that are only at 1% complete including project requirements, structural steel, and storefront. This is because the structural steel was getting prepared to be delivered and started once the proper amount of concrete work in the foundations was finished. Some items that are far along in terms of progress include concrete, elevator, and earthwork. These items are at 31%, 42%, and 41% respectively. The complete November 2016 requisition data can be seen in Appendix A to give an outline of how the major items in the project are carried out and how their percent complete is tracked.

According to the most recent requisition as within the date range of this MQP report, the amount that has been spent on the project up to the January 4th 2017 requisition is $5,078,090.90 which is 13.5%. From the amount of money spent according to the original contract sum, the project in terms of finances is almost 14% complete and has doubled since the November requisition. Some important percent complete amounts that are significant to note at this time is that concrete is 49% complete and steel is 61% complete.

Some savings have been realized throughout the project as well through value engineering. One large VE item was the substation mechanical screen and WT8 Panel, it was revised to realize a $235,577 credit to the budget. Other value engineering items that were discussed were metal panels, pavers, the green roof, roof davits (which if they were eliminated could result in savings), exterior brick, and stainless steel vine support. These value engineering options allow for money to be saved in the budget and allow for overages or spending money elsewhere. One area where savings were applied was related to the drywall contract. The project team decided that significant savings could be used to afford the price of a higher qualified subcontractor who would get the job done and done well. The use of Manganaro and Island for the drywall and insulation would result in a $181,477 overage on the budgeted line item. The impact of selecting a less qualified subcontractor who offered a lower price could result on a higher total cost and negative schedule consequences that the over budget value was worth it.

3.5 Schedule

The schedule for the Foisie Innovation Studio began with demolition of Alumni Gym starting in May of 2016. The original schedule is said to have the project completed in the fall of 2018. The preliminary schedule can be seen in Appendix B. From May of 2016 through February 1st 2017, a great amount of the project has been completed. Alumni Gym was completed abated and demolished. Groundbreaking for the new building took place on August 31st, 2016. After the groundbreaking, construction began with driven piles, soil retention, and site work. The entire foundation for the building was completed and waterproofing was nearly completed. Structural Steel began in late December of 2016 and as of February 2017 is nearly to the top of the fifth floor and soon to have the roofing steel attached to the L shape. Some snow has impacted construction and the superintendent Matt Lafond says they are only about five days behind schedule. He is confident that those days will be recovered once the weather becomes nicer and other packages are being constructed. The topping off ceremony took place on February 23rd, 2017.

3.6 The use of BIM

The designer and construction manager selected for this project as well as WPI are knowledgeable to varying degrees in the use of BIM. The intent of WPI for the use of BIM on this project was outlined by the Board of Trustees in which elements of BIM were to be included early in the project to assist with coordination and interoperability amongst the design team, contractor, and owner, thus promoting collaboration. Therefore, the Request for Proposal for design and construction services for this facility required providers of these services to be knowledgeable of BIM for different stages of the project. In this case, the RFP documents used to invite design and construction professionals for this facility contained an explicit statement requiring BIM-based capabilities from these professionals. However, no specific terms were included in the contract to define the scope and extent of the use of BIM in the contract language.

The design and construction of the Foisie Innovation Studio is now being used to further advance the use of BIM at as a tool at WPI, which among other purposes, will coordinate the creation of information during design and construction transferred to the facilities management (FM) department when the construction is completed in 2018.

As a result a very interesting and iterative collaborative process has taken place among the owner, designer and construction manager that has “forced” WPI to think critically as to what information, is really needed, what is desirable and what is not needed. Also, this has provided an opportunity to deeply examine the role of BIM in this process and what are desirable uses. Finally, specific type, structure and content of data, including BIM-models to be handed to the owner at the completion of the project has been clearly defined. This has been accomplished by promoting the dialog among project participants. Chapter 5 of this report takes an in depth look at the current and future uses of BIM at WPI.

It has been agreed that the CM will incorporate building objects with their corresponding information into the BIM model that are of primary interest to FM staff. This information, which is primarily the MEP type, will be part of the record model and will be exported into a spreadsheet feeding directly into WPI’s computerized maintenance management system (CMMS) system. Subcontractors are required to provide this information in their submittals.

BIM was used by the designer primarily for the production of well-coordinated 2D drawings as well as for 3D visualizations of the project. The construction manager is using BIM for the 3D coordination of MEP trades with FP and structural systems. The subcontractors will be submitting their as-builts in a fashion that will coordinate with the model. The construction manager also uses these models for their quantity takeoff as well as for supporting cost estimates. BIM is also used to generate information for the FM at the end of the project

3.6.1 BIM for Design

Revit is a building information modeling software for architects, structural engineers, MEP engineers, designers and contractors (Autodesk, 2016). Revit was the BIM tool used by Gensler in their efforts to design the Foisie Innovation Studio. The model of the Foisie Innovation Studio can be seen in Figure 4. Revit can also be extremely useful upon completion of a construction project. Since the model has the capability to contain information related to the building components, it can be passed along to facilities management for operational and maintenance purposes. For example, if the Revit model contains the as-builts of all mechanical systems, it will include the location of every shutoff valve in the entire building. These as-built details can be exported from Revit to a viewing platform that allows for additional information to be integrated into the interface. If a situation arises that requires the attention of one of the valves, it can be located quickly and easily be the facilities management team. The rapid response from facilities management to such issues will inevitably reduce future mechanical issues pertaining to the building.

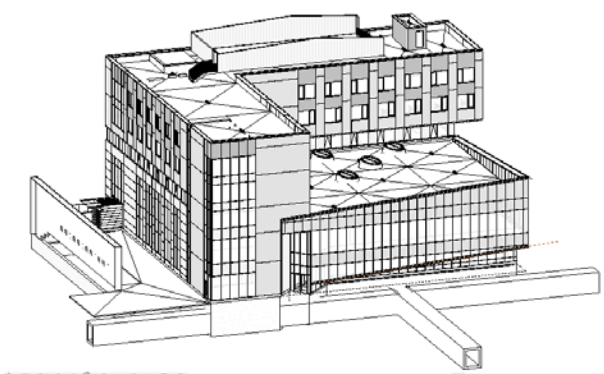

Figure 4 Revit Model of the Foisie Innovation Studio

3.6.2 BIM for Construction Management

Navisworks is a program that converts large Revit 3D model files into smaller 3D models for viewing purposes are far more manageable for a large number of team members. Shawmut Design and Construction uses Navisworks for the Foisie Innovation Center project as a means to track the coordination of various trades on site. Navisworks essentially is a viewing interface that can receive various coordination models and combine them into one master plan to be viewed. The Navisworks model of the structural components of the basement and first two floors of Foisie can be seen in Figure 5. One of the primary purposes of Navisworks is that all the subcontractors' coordination models are imported to run clash detection. Clashes most commonly occur between MEP systems involving pipes, fittings, and ducts. Other clashes occur among structural components in the building. It is most common to find clashes in confined areas. The use of the clash detection software can avoid delays, design changes, materials costs and budget overruns (BIM Handbook, 2017). The construction schedule that is made in Primavera is interoperable with Navisworks and can be used to add schedule data to the model.

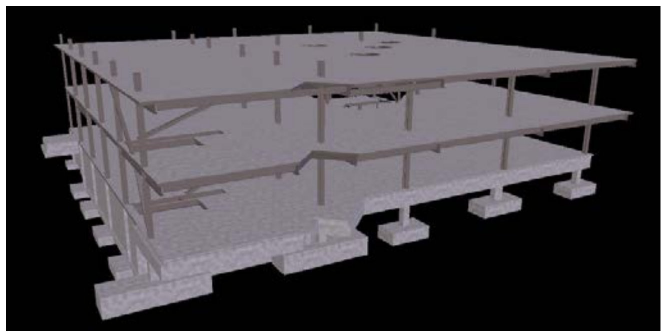

Figure 5 Navisworks Model of the First Two Structural Floors

Procore is a cloud based construction management software. It is used by many general contractors, primarily for document management purposes. Procore provides a platform for users to collaborate on projects and view various documents, including submittals, RFIs, contracts, schedules, and drawings. It also enables contractors to easily create punch lists and assign responsibility to a specific individual once they have been added to the project directory. Everyone from general contractors and architects to engineers and construction management firms are able to edit and share information about the project from the jobsite. Shawmut Design and Construction uses Procore on the Foisie Innovation Studio project in order to maintain proper documentation of the project, and improve and simplify collaboration among team members. Procore allows for all different file types, such as Revit and Navisworks files, to be saved in the cloud and be seen and downloaded by anyone with access.

3.6.3 BIM for Facilities Management

Building Information Modeling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. (Autodesk, 2016) The implementation of Building Information Modeling and facilities management is slowly coming to the forefront of the construction industry and gaining momentum. At the conclusion of a project, the handover process of documentation from the general contractor to the owner can be overwhelming. The owner receives electronic and paper information regarding the building's structure, MEP systems, cost information and schedules, and much more. This may take months for the owner to sort through the information to integrate it into one organized system that can be easily accessed. The current plan for WPI and Shawmut to conduct the handover process will consist of Shawmut continually updating their Revit and Navisworks models. At the completion of the project, Shawmut will hand over the most complete as built models in Revit and Navisworks to WPI having subcontractors give them as much information as possible about their MEP systems and other equipment installed. (Lussier, 2016)

Currently, BIM technologies are being used to make this handover process much easier for the owner. For example, the U.S. General Services Administration (GSA) is requiring delivery of spatial program information from building models for major projects; the U.S. Presidential Executive Order 13327, promotes the creation of a common infrastructure to facilitate effective information sharing/reuse. (Alvarez 2014) Building information modeling is currently using computer software to create a three-dimensional (3D) model of a project where attributes and information can be stored on specific physical systems in the model. (Bertin et. al. 2011) A WPI project team created two three dimensional models that implemented BIM for facilities management for the Sports and Recreation Center. (Bertin et. al 2011) They used Autodesk Revit to create the model, then used Autodesk Design Review to display the model with the information associated with its components. Since BIM was not used collaboratively through the construction of the WPI Sports and Recreation Center, the creation of the models and supplying the necessary information is a time consuming process. U.S. General Services Administration (GSA) has initiated several pilot projects to investigate the implementation of BIM for facilities management to try to get all parties of a construction project to work collaboratively with BIM throughout the entire project. (Alvarez 2014)

BIM technologies currently have limited standards for their use and handover to an owner. There are new and improving specifications that are being used to facilitate the exchange of electronic information of BIM object data. Two of these specifications are the Construction Operations Building Information Exchange (COBIE) specification and the Industry Foundation Classes (IFC). (Alvarez 2014) IFC if the most successful standard for interoperability within BIM. (Alvarez 2014) The IFC allows interoperability between different software programs and BIM because it is the open and neutral data format for openBIM. (Model Support Group) With the implementation of COBie, IFC, and other resources, BIM can be effectively and easily transferred to an owner for facilities management.

4.0 Design Process

A crucial component of the Foisie Innovation Studio project is the notion of collaborative design and construction. The benefits of collaboration among project participants are becoming better understood by owners, architects, and construction managers who become more involved at the early stages of design and continue this level of involvement through construction, until the new building opens. The traditional and older method of construction has been the design-bid-build approach. This caused construction projects to take longer than they should have and also led to adversarial relationships with many disputes and headaches because each discipline in the project was separate from one another. Under a collaborative approach, all project members participate in decision-making and buy into the design acting as one team. This allows for designing and construction to overlap to a large extent. Site work and foundations can be occurring while final designs on room finishes and furniture is still ongoing. This collaborative approach also allows for estimates to be ongoing as design decisions are formalized and documented. Overall, the collaborative experience allows for individuals involved in the project to voice their opinions and solve issues in a participatory fashion.

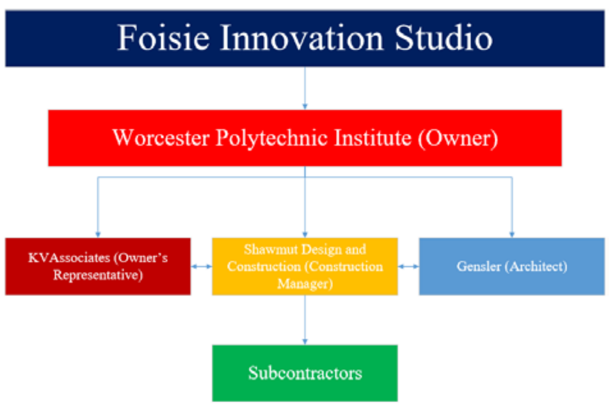

Figure 6 Foisie Innovation Studio Project Team Breakdown

The Foisie Innovation Studio project greatly utilizes the collaborative approach. WPI, Gensler, Shawmut, and KVA all work together and have many different meetings to advance the project, stay within budget, talk about potential changes, and deal with ongoing dilemmas. The organizational breakdown as described in section 3 can be seen in Figure 6. To fully implement the collaborative experience, the project conducts various meetings and settings that the project

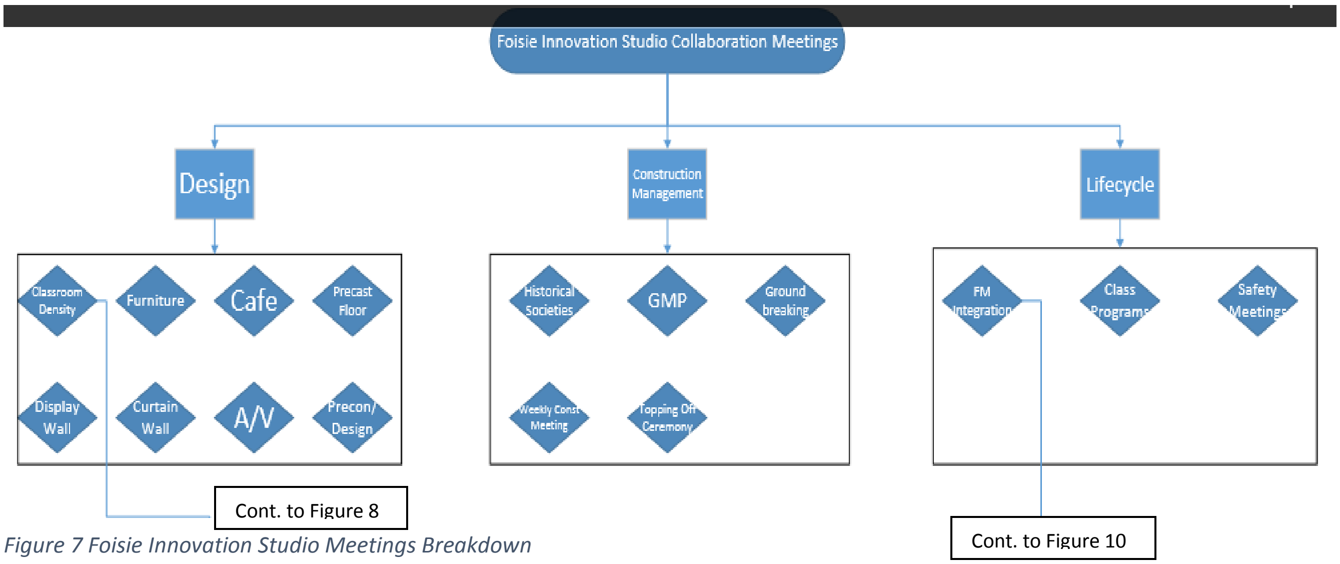

Figure 7 Foisie Innovation Studio Meetings Breakdown

members participate in. Several meetings were conducted throughout the project which demonstrated the collaborative experience. The complete listing of various meetings and issues can be seen in Figure 7. The types of meetings that were carried out were grouped into three separate categories being design, construction management and lifecycle. Later in this section, several of these collaborative issues and decision making topics are discussed in greater detail.

To further assist collaborations, management information systems play a vital role in the organization and success of a construction project. Shawmut uses the platform Procore as their management information system. Procore is broken down into several sections including RFI's, submittals, meetings, schedule, photos, drawings, specifications, and documents. This easy to use site allows for an extremely organized system of data for the Foisie project. For example, all of the meeting minutes are uploaded after every meeting and are in chronological order, making it easy to refer back to them at any point in time. All of the design drawings are located and organized by type or by discipline as well. Marked up and changed drawings are also included and also point to the RFI that it is associated with. Another feature of Procore is that it can be shared with other members as well; WPI and Gensler both have access to Procore and can view the items that Shawmut uploads into the software.

WPI also has its own management information system as well which is Schooldude. Schooldude is used by WPI for facilities management. In this program work orders can be made and sent to specific workers to complete. Once the order is complete the workers can input information regarding costs and materials that were used. Schooldude also keeps track of equipment that WPI owns. (Tomaszewski, 2016) Specific information such as location, warranty information, and original cost can be seen for equipment such as air handling units, vehicles, and fire extinguishers.

4.1 Collaboration of Design Aspects

The first area of collaboration deals with design aspects of the Foisie Innovation Studio. Various topics that were discussed in terms of design among the project team are shown in Figure 8. Design topics were always being discussed, changed, and sometimes removed depending on how the team agreed was the best way to solve a particular Issue.

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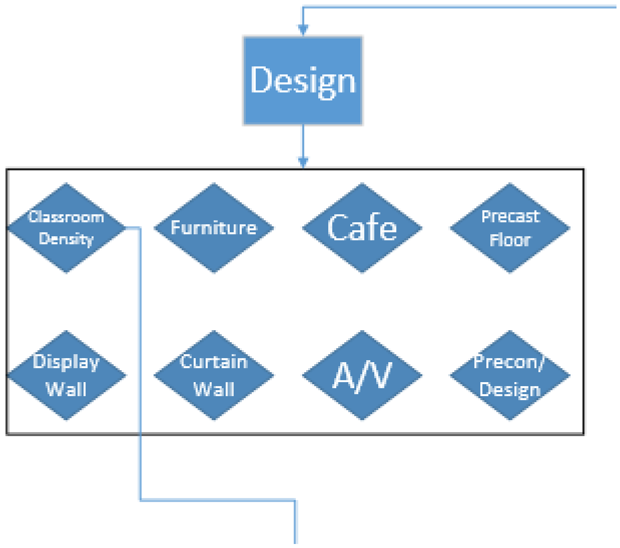

Figure 8 Design Meetings Breakdown

4.1.1 Pre-Construction Meetings

The first type of meetings that took place with all of the group members were preconstruction and design meetings. These meetings were held bi-weekly and started in March of 2016 before demolition of Alumni Gym even started. There were five meetings that were held from March 15, 2016 to May 24, 2016. The main topics that were discussed during these meetings dealt with design considerations for the major MEP systems. The first preconstruction design meeting discussed the HVAC systems and equipment associated. The collaborative piece was very present during this meeting since there were action items for both WPI and ARUP. WPI was going to provide preferences on the various types of equipment that will be installed in the building as well a list of preferred manufacturers as well. This showed the collaborative nature that WPI and ARUP were going to decide on equipment and manufacturers together once information was gathered from both sides. Shawmut would then join in the collaboration once bidding was to begin. Shawmut was going to work with the information from WPI and ARUP and first descope bidders to get the best prices possible. After a few subcontractors were selected, they would then be given the information of the manufacturer specific information. The lower bidders would then be given the specific information and adjustments would be made to see their final bids. The listing of preconstruction meetings can be seen in Appendix C.

4.1.2 Green Roof Design

The goal is to design a green roof under the impression that the green roof will not be added. The design team with Gensler has currently designed the roof to include a retrofitted green roof. The design this project will be creating will not include the option of a green roof. During the process many things need to be evaluated. The school is looking to ascertain a LEED certification, and analyze the short and long term cost impact of the green roof. There are not any regulations or design standards for a green roof, so information from the Worcester Unum building green roof is being used as a guide.

The first task is to examine at the design of the current roof structure being used by Shawmut and Gensler. The design of the roof structure needs to be evaluated for what the design loading was, and how the green roof integrates into the structure of the roof itself. The methods that were used needs to be looked at too. As well as the cost analysis, schedule, and constructability of the roof and retrofit done by Shawmut.

The second task is to figure out which materials will be used and the maintenance and construction access needed for the roof in order to figure out the loading for the roof. The Massachusetts state building code also needs to be obtained to find snow loading, and other typical loading for this type of roof. The design will also include how much self-weight of the roof needs to be included for each beam or girder. The loading will be outlined in a table or spreadsheet for easy access. Once the loading is identified the design process will need to be one according to the American Institute of Steel Construction (AISC). These two methods are the Load Resistance Factor Design (LRFD) and American Stress Design (ASD).

The design process will evaluate the design used by Shawmut compared to the new reduced loadings. The beams will then be examined to see the extent they are over designed, or if reductions in size or placements can be implemented.

Each beam and girder will be evaluated according to each unique load case based upon the predetermined design load. The beams will be designed with a set of hand calculations looking specifically at: design moment, deflection and deflection limits, and flange width. The next step is to compare the hand calculations to an excel sheet and then to RISA 2D to make sure the calculations were within an acceptable variance.

Once the calculations have been confirmed, a new design needs to be assessed in order to provide the most effective roof, while being cost effective. Each beam and girder size and shape needs to be reevaluated based on the new loading and see if reductions can be made. (Cavanaugh, 2016)

The green roof design aspect of the project was not carried out further than the background information as stated in the prior narrative. The reasoning for the removal of this section and design process was for a multitude of purposes. One of the major factors for this was because designs for the green roof were already factored in to the designer's drawings. It was discovered early on in this MQP that Gensler had designed the green roof for a retro fit. WPI did not want to spend extra money on the green roof design, but the architect kept the retrofit design in the event that WPI wanted to pursue it later on. This created a dead end for the design of a green roof for this project. Looking at a design where there is not green roof on the Foisie

Innovation Studio would be a waste of resources since it is structurally built to support the retro fit. Also, since the structure is already determined for the building and won't be changed, it would also be a wasted effort to redesign for a different green roof. The only factor that will change will be the architecture and landscape of the green roof, if WPI decides to tackle that venture. This resulted in the third member of this group transferring to another group where there was a more pertinent design challenge to be solved.

4.1.3 Curtain Wall

WPI noted concerns regarding the esthetics of the building's curtain wall. Additionally, they felt the windows in the dormitories would not allow for enough airflow, and would be difficult for the students to open and close. Four unique curtainwall design assist meetings were held weekly from September 6, 2016 to September 27, 2016 with WPI, Shawmut, Gensler and Chandler to resolve these concerns. The full listing of curtain wall meetings can be seen in Appendix C. Shawmut tracked the cost implications of changes, and held these meetings in their site trailer. Gensler was responsible for detailing the design for construction, and had to do so according to Chandler's product criteria. Chandler provided pictures and elevations at some of the meetings for discussions to take place of potential curtainwall ideas. Some of the details that were discussed at these meetings were toggle systems, firestop details, and samples. The new toggle system that was agreed upon added an extra $60,000. In regard to the dormitory window, Gensler created a new design and the change was approved by WPI and the other project members since it allowed for better air flow and would allow for an easier mechanism for opening the window.

4.1.4 Active Learning Classrooms

Within the Foisie Innovation Studio there are going to be three active learning classrooms. Within these classrooms there are going to be special televisions that will be used for unique teaching purposes. WPI was undecided whether these televisions should be mounted on movable tracks in the ceiling or on carts with wheels. There were pros and cons with both systems. The tracks in the ceiling made for more floor space, but would block students' vision and block wall or white board space. In addition, the professors at WPI requested that the rooms be capable of holding 60-80 students. When the professors saw the floor plans of the rooms with the furniture they said that the classrooms looked like they could only fit up to 48 students. Throughout the discussions of these issues, many parties input their opinion and expertise to reach conclusions. From WPI, professors and project team were actively involved in the decision making process. Gensler, KVA, and Shawmut were also heavily involved in the process. Questions regarding the televisions were raised on August 23, 2016, and the classroom density issue was brought to the team's attention October 25, 2016. Discussions surrounding both issues extended into December, and the final consensus was reached December 6, 2016.

At construction meetings, Gensler said that they were going to find some past projects where the square footage per student was similar to the square footage per student in the active learning classroom. Gensler came back and said that was a somewhat unrealistic idea since no two rooms in different buildings are the same. WPI and Shawmut created the idea to tape off the room dimensions in a large space (such as Harrington Gym) and place some of the mockup furniture, and the desired amount of people in the area. This was a way for the professors and students to see the rooms at full scale.

Gensler and WPI did more research into the density of the active learning classrooms and both parties found colleges that they could use as examples. MIT has a classroom similar to the classrooms for Foisie that are 25 SF/student which is closer to the active learning classroom ratio of about 22 SF/student. Questions also rose about whether circular tables may be a good fit instead of the rectangular and square tables that have been on the agenda. All project parties agreed that more research needed to be done. WPI suggested that a field trip be taken to one of the other colleges mentioned that had similar classrooms. This seemed risky since no two classrooms are alike. WPI also expanded upon the previous idea of taping the dimensions on a floor such as Harrington, and using two walls and dividers to simulate and actual room. One other suggestion made was that the virtual reality goggles could also be used to create mockups of the rooms for people to experience.

WPI took a field trip to Boston College where the active learning classrooms had round tables. WPI was more intrigued in round tables (66" diameter) because it promotes active learning and collaboration. These tables seat nine students and offer much different learning experiences than the rectangular active learning tables.

A meeting was held on 12/6/16 with two WPI professors that will be using the classrooms in Foisie. One is a physics professor and the other teaches a Great Problems Seminar (GPS) class. The professors were brought in to gauge their ideas on the various configurations and types of tables to be used in the classrooms. Both professors seemed to agree that the two smaller classrooms were only big enough to fit 56 students and the large classroom was able to accommodate 64 students. Both professors seemed to think that it would be possible to have a 90 student class when the partition between the two classrooms was lifted. This raised some questions of what would happen if the partition did not work properly one day and also scheduling for those classes should be on a term basis and not daily basis. There was also some dispute over the use of rectangular tables or round tables.

The final conclusions were made on classroom density with the first floor larger classroom will have sixty four students and the two second floor classrooms will have fifty six students. The larger classroom will feature eight pods of eight students and the smaller classrooms will each feature seven pods of eight students. The pods will be made up of two rectangular 30”x72” tables that are put together to create one 60”x72” table.

A flow chart was developed to show the collaboration and involvement of the various members of the project. The chart outlines the major teams like WPI, Shawmut, KVA, and Gensler, as well as other individuals such as the professors. The chart describes how the classroom density and furniture discussion developed as more people became involved in the discussions. The chart shows how various configurations and table sizes were ruled out and the reasoning behind them. This chart can be seen in Figure 9.

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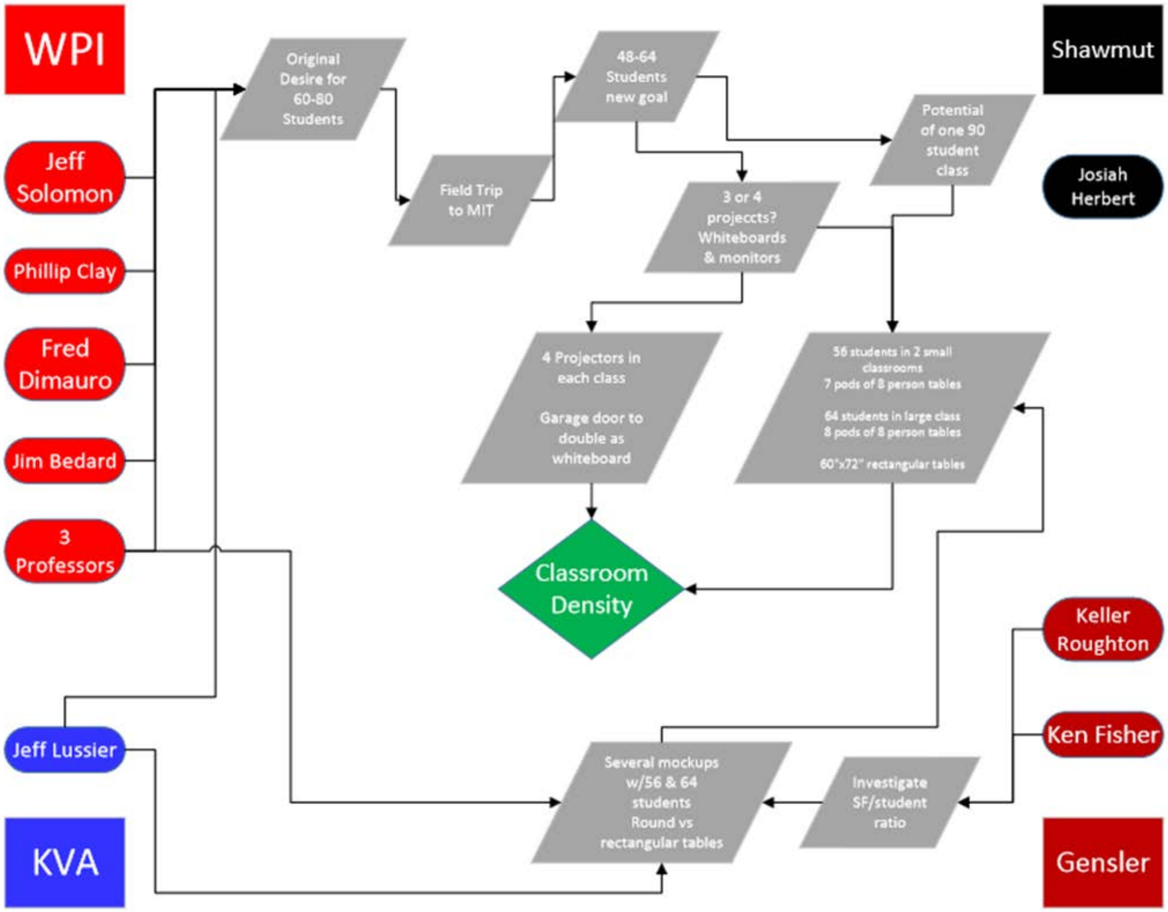

Figure 9 Classroom Density Collaborations Flowchart

4.1.5 Security Gate

There were several talks among WPI, Gensler, and the code consultant in regard to a security gate to be located at the bottom of the staircase near the café of Foisie. WPI's concern was that students would be able to go down near the door to the basement and not be able to be seen. These discussions took place from August 23, 2016 to September 20, 2016. WPI and

Gensler went back and forth with one another going over different designs such as a full gate or half gate and if it should be placed at the bottom of the stairs or at the first floor level landing. After several weeks of discussions and drawings the decision was made to have a full gate at the level landing at the top of the stairs that lead down to the basement. The collaboration among all parties involved in the discussions shaped the safest and most cost effective solution.

4.1.6 Café

In the corner of Foisie at the WPI Quad, there will be a café located behind the first stair case. Initially, WPI wanted to have a kitchen to be located in the café for a wider variety of vendors to be chosen. The issue with this type of construction was it would require large scale kitchen equipment that would drive up costs for the project. Between WPI, Shawmut, and the architectural assistance of Gensler, the consensus was made that the added cost and loss of space for the café were not worth the effort. Through many meetings and many months of discussion, it was determined that there should only be additional storage made in the café for a vendor that can stock its inventory from an outside source. In early December 2016, a survey was released to the faculty and students of WPI of their preferences for what type of food, drink, and prices should be a part of the café.

After the data from the survey was recorded, the favorite options of those that were surveyed were for the café to feature bagels and juices. WPI began to have interviews with different vendors that fit these criteria and initially had two vendors (one for bagels, one for juice) that would both occupy the space. As of 1/17/17, one of the vendors was skeptical and may back out. As of 2/7/17, it appeared that Auntie Annie's Pretzels will be the vendor of the

Foisie Café. Several issues remain however with having enough space for seating, the congestion in that area, as well as fire code issues.

4.1.7 Precast Flooring

The flooring for the Foisie Innovation Studio had an initial design of precast slabs. It was later determined that these slabs would not fit through the structural steel that would be in place when the slabs arrived. This led to discussions among project members about alternative designs. One alternative was a Terrazzo precast link that would have small slabs placed on top of and interlocking with each other. There was another alternative for a limestone floor, but that would have driven up the cost of the project by $350,000. Some companies such as BPDL and Coreslab were considered. As of 11/8/16, BPDL said that they would be able to install the precast flooring in May.

Coreslab was signed up to do the precast flooring the week of 12/5/16. They were beginning to prepare shop drawings and provide samples as early as possible to be able to try to have those ready for May, when the schedule indicates. Coreslab was actually the second lowest bidder on the item, but was able to be talked down to the lowest bidder’s price so that they could win the work. The price that they came to also matched the budgeted price that was in place for that item.

4.1.8 Waterproofing

Two methods for waterproofing foundations were brought up by the Shawmut project team. The two methods were a waterproofing that was applied by large sheets that cover the foundation walls and footings, or a penetron spray that is blasted on to the concrete. Initially, the

Shawmut supervisor (Matt Lafond) said that he recommended the penetron because he has used it in other projects and had much success. WPI was still skeptical since it would create an additional cost of $20,000. After discussions, the project members decided to go with the sheet application and apply the penetron spray only on the elevator pits.

The waterproofing was narrowed down to two contractors, Spillane and Superior. Spillane was $20,000 higher than Spillane at $90,000. Both are union so the project group agreed to go with Superior at the lower cost of $70,000 which is right on target with the budget. Superior was awarded the bid on 11/15/16.

4.1.9 Feature Wall

In the main lobby of the first floor of the Foisie Innovation Center there is going to be a feature wall that will display achievements, current events, and many other aspects of WPI. A long process was spent on determining the design of the feature wall, what components it will have, and materials that it will be made out of. Talks went back and forth of what type of media technology would be used to show various types of media and messages on the wall. The main discussions were whether televisions or a projector be used to have images on the wall. There were also talks about a hybrid model that had some televisions and projection as well. The main concern for the projection is that during the day time, ambient light from the windows and skylights would interfere with the image from the projector. The final two designs that the choices have been narrowed down to is a full monitor wall and a mostly monitor wall with a section for projection. From the IT department’s point of view, they said that both wall configurations would cost the same to maintain and keep updated.

4.1.10 Northwest Water Main

The water main of the northwest corner of the Foisie Innovation Studio became an issue when Matt Lafond in the field noticed that the pipe only has 2.5’ of ground cover. Water main pipes generally have around 5’ of cover to protect against freezing conditions. The project team decided that this was a pressing issues that needed to be dealt with immediately.

One solution was to bury the pipe deeper to achieve the correct amount of ground cover. The idea went back and forth between WPI and Shawmut and it was determined that the solution of burying the pipe further and potentially relocating it would cost too much and take too much time. Another solution was to add the necessary soil on top of the pipe to achieve the proper cover that was. This was also ruled out since the design team came back with the notion that the drastic grading change in that location would hinder the design of the promenade in that location.

After these talks were had it was determined collaboratively that a hybrid approach would be used. The idea is to add only a few feet of cover above the finish grade to add additional cover without interfering with the promenade grading and design. The other half of the solution is to add 4” of insulation around the water main to protect against freezing conditions as well. The project team believes this approach is the best for the situation and most cost effective.

An architectural study was performed to determine how the 12” of additional cover would affect the landscaping plans. The study showed that the slope of the land immediate downhill from the northwest staircase is currently 5.5% and would change to around 8.1% with the additional fill. This began talks of extending the staircase and add a landing to help with providing some of the 12” cover. The staircase would split in two directions, one towards the back of the campus center and the other down the hill towards the parking garage.

4.2 Collaboration of Construction Management Aspects

The second topic of collaboration in the Foisie Innovation Studio is the construction management aspect. Shawmut, being the construction manager for the job, was responsible for these topics. The listing of some of the CM collaboration topics can be seen in Figure 10

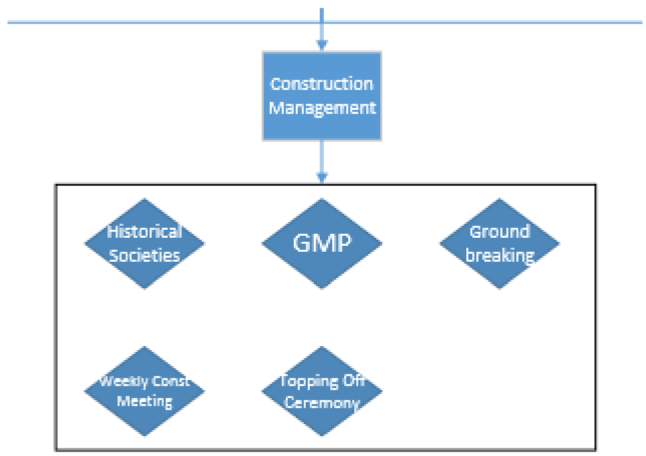

Figure 10 Construction Management Meetings Breakdown

These topics concerned mostly cost and schedule items such as the GMP, weekly meetings, and various ceremonies conducted for the project.

4.2.1 Weekly Construction Meetings

WPI, Shawmut, KVA, and Gensler meet once a week for their construction meetings. This is where some of the best examples of collaboration among the project members can be seen. Shawmut leads the meetings by going over the meeting minutes from the previous week. The full listing of weekly meetings and most important topic can be seen in Appendix C. These issues are discussed by the project team and announcements are made whether or not there are any new updates for the items in question. Most of the minutes that are brought up usually only have a quick remark from the person who is responsible for the item at that time. For example, for an item like water permits, Matt Lafond only had a few quick updates explaining that the permits were going to be retroactively pulled by the subcontractor R.H. White. There are other longer standing issues that can sometimes lead to hour long discussions among all member of the project team.

As discussed in section 4.1.4, the classroom density topic has been an ongoing and lengthy topic that is being discussed. The classroom density discussions have been a true realization of how the collaborative project management experience develops. WPI, KVA, Shawmut, and Gensler all contribute their opinions on the matter. Gensler develops the drawings, mockups, and different scenarios as they see appropriate. The WPI project team, as well as the professors that will be using the classrooms, were part of the debates. Jeff Lussier from KVA also gives consulting advice on how to create the best scenario for all parties involved.

The issues that are discussed among the team are the maximum amount of students the classrooms can hold, the shape and size of the tables, technologies such as monitors and projectors, whiteboard space, and dividing walls.

4.2.2 Consecutive Estimates and GMP

In a guaranteed maximum price contract, the GMP is not always determined at the beginning of the project. Many estimates can be made along the way as the design and construction develops to give a much more accurate figure for the owner and construction manager to agree on. For the Foisie Innovation Studio, there were several estimates made at various milestones. There was an initial estimate given at the beginning of the job when the preliminary design of the building was created. This gave a baseline for WPI to determine whether they wanted to move forward with the project. More accurate estimates were created once new documents were released. There was an estimate from the reconciled design documents with accepted value management. There was another estimate when the 60% construction documents were released as well as the 100% construction documents. A projected GMP was also determined for items that Shawmut had good confidence in the numbers that would be carried. These estimates eventually grew into the final GMP contract which was signed the last week of January 2017. Some of the items in the project were already bought out before the GMP was created and signed because of the nature of the project. The reasoning for this is to ensure that the CM and owner are happy with the GMP final value and also to have the best accuracy as possible for the value of the project. The final values for the GMP can be seen in Table 4.

Table 4 GMP Breakdown

Subtotal Direct Costs	$35,331,975
Indirect Costs	$1,701,785
Subtotal Construction Costs	$37,033,760
Contingency	$1,111,013
Total Construction Costs	$38,144,773

The final GMP contract for the Foisie Innovation Studio was agreed upon at a total of $38,144,773. The total direct costs seen in the table are those costs that are associated with labor, materials, and equipment. The indirect costs are insurance, overhead and fees, as well as permits. The final item is the contingency which is the leeway given to the construction manager for any unforeseen expenses that may arise throughout the project. This is to provide some safety for the CM and owner if any drastic events were to occur that needed additional funds.

4.2.3 Historical

Mass Historical Society delayed the project about a month. This was due to the fact that WPI had first contacted Worcester Historical Society and everything was in place to begin the project. Mass Historical Society got word of what was going on and wanted to have a say in how operations were handled. They were slow to respond and never gave true approval of when they wanted the project to start. WPI and Shawmut could not wait any longer and began demolition.

4.3 Collaborative Style Summary

Overall, the collaborative approach for design and construction at the Foisie Innovation Studio was quite successful. The collaborative approach along with the design-build strategy allowed for a fast track project that made the most of time and money. The GMP contract also allowed for great collaboration amongst team members to be sure that the price of the building and its components were accurately represented. As described in Section 4, several meetings were held having various members and always worked towards the common goal of keeping costs down, and making sure that all project members were satisfied with the results. Keen attention to detail was observed throughout the project and all collaborations were professional. From weekly construction meetings, facilities management integration, classroom density and more, the project team worked very closely together and incorporated all necessary personnel to yield the best results for the project. Organization was key throughout the collaborative process as meeting minutes were tracked, as well as RFIs, submittals, and the development of the GMP. The collaborative experience among the project team members allowed for all information about the project to be known by all the involved parties, allowing for better communication, problem solving, and presenting the project data to others.

5.0 Building Information Modeling (BIM)

The design and construction of the Foisie Innovation Studio project is being conducted in a collaborative fashion as described in previous parts of this report. This approach has benefitted the project in many different ways. Building Information Modeling (BIM) has been used to some extent in supporting this collaborative effort, however, the potential benefits that can be derived from its use can be greatly enhanced by taking a more systematic approach for its use in future project. This section provides specific recommendations as to how the design, construction and facilities management can be integrated in the future at WPI.

5.1.1 BIM for Design (BIM Execution Plan)

When BIM is used in a given project, a practice has developed to incorporate into construction documents which is known as a BIM Execution Plan. The BIM Execution Plan defines uses for BIM on the project (e.g. design authoring, cost estimating, and design coordination), along with a detailed design of the process for executing BIM throughout the project lifecycle. These BIM execution plans are used to contractually convey standards that will be specific for the BIM technologies to be used on a construction project. The topics address different aspects such as who has privileges of access to the model of the building in question, who is responsible for updating the model, conflict-resolution, and much more. This document would allow WPI to establish specific requirements for the construction manager and the designer as to how they will use BIM technologies in the project. The BIM Execution plan outlines the people that are involved, what rights they have to BIM information and the specific types of BIM practices that are used. The BIM Execution Plan is an extension to the project contract and creates a guideline for how the project will be run from the basis of BIM. This MQP created a BIM Execution Plan containing fourteen major sections in which BIM can be related to a project. These sections can be seen in Table 5. The plan first establishes BIM related milestones such as when the 3D model will be complete, the people that will be involved, accepted BIM platforms, and much more.

Table 5 BIM Execution Plan Table of Contents

BIM Execution Plan Sections
1.0 BIM Execution Plan Overview
2.0 Agreement
3.0 Project Overview
4.0 Key People and Contact Information
5.0 BIM Use
6.0 BIM Meetings/ Coordination
7.0 BIM Applications and Hardware
8.0 Additional BIM Tools
9.0 Additional Degrees of Modeling
10.0 Subcontractors
11.0 Deliverables
12.0 Settling Grievances
13.0 Changing or Adding to the BIM Execution Plan
14.0 Signatures

The full BIM execution plan can be seen in Appendix J. This document lists the full strategy on how to incorporate the BIM Execution Plan by providing a skeleton document that can be filled in by the participating project members.

A specific version of the proposed BIM Execution Plan document was used to illustrate how it could be used in design and construction of the Foisie Innovation Studio. This document was color coded to represent three different aspects. The first aspect is green text which represents items that were completed with BIM technologies for Foisie. Red text represents areas that were not utilized in the Foisie project, but are recommended for future projects. Finally, blue text illustrates items that were conducted on the Foisie project, but were not achieved through BIM. For example, there were many areas where the Foisie Innovation Studio project used BIM such as Revit to create their 3D model. The capability of this BIM technology could have been used to do much more than just model the building, it could have been used for code validation, building systems analysis, space management and much more that is outlined in the BIM Execution Plan color coded copy. The detailed version of the color coded BIM Execution Plan for the Foisie Innovation Studio can found at the end of this report in Appendix I.

5.1.2 BIM for Design (BIM-based staff position on Campus)

Along with a BIM Execution Plan there is a need to create a position to be dedicated to supporting the use and implementation of BIM at WPI. This position could be housed by the facilities management department. This position could be filled by a full-time or part-time individual and could have the title of BIM Execution Specialist. The job description would include the handling of all of WPI’s BIM related affairs from new and existing facilities including design, construction, and facilities management. This position could be filled by an outside individual that can be interviewed and hired, or by a current WPI employee that could learn more about BIM technologies, or a student position that could work on specific BIM related tasks. There are various cost implications with any of those options which would require a cost/benefit analysis before undergoing any action.

The BIM position on campus would allow WPI to have better input in construction projects and allow for a streamlined system for how data and documentation is transferred from the construction manager and designer to the school. The BIM employee could be contractually bound to a construction project on campus through the BIM execution plan that would have been signed by the project participants. In terms of design, by being contractually involved the BIM employee could work side by side with the designer to coordinate BIM model updates as the design evolves and even incorporate owner-based components of the design being implemented using BIM technology.

Another example of where a BIM position could be useful is for facilities management. It could create one comprehensive model with all the information that WPI requires. In the case of the Foisie Innovation Studio, the construction manager had the personnel and ability to create this type of model, but at the time WPI deemed that the facilities management department staff and infrastructure was not ready to take advantage of such a level of complexity.

The recommendation of having a BIM position on campus would allow for WPI to be able to have all construction projects be represented in 3D models and have estimating software, remodeling capabilities, and much more at their fingertips from a design standpoint.

5.1.3 BIM for Design (BIM Assisting Tools)

Another aspect where BIM tools could have significantly helped during the design process of the Foisie Innovation Studio was 3D rendering and virtual reality. In the case of determining classroom density, only 2D floor plans were used to illustrate the arrangement of tables and chairs in the classrooms. This made it difficult to accurately visualize the usage of 3D space to determine the most favorable furniture arrangement for teaching purposes. Therefore, a series of meetings among stakeholders and a physical mock-up using an existing space on campus was used for this purpose. What could have been done to enhance the vision of the design was to create 3D digital renderings of the rooms to show the tables to simulate different arrangements. 3D digital objects of people and furniture could have been placed in the room as well to paint a better picture of how space would be used in the classrooms. This could also have been done using 3D Digital Extended Augmented Reality or Virtual Reality (VR). The designer and the construction manager on this project both have computer-based capabilities such as

Figure 11 Virtual Reality and BIM

holographic computers and virtual reality headsets to provide an immersive experience for the stakeholders, allowing them to interact with their furniture arrangements and space before a decision was made. Figure 11 shows how virtual reality would look and how a 3D version of a building can be seen as if a person is standing in front of or inside it. This could have given another perspective as to which design should have been chosen and at the same time to save time and resources.

This application could have also been used at other meetings including a Board of Trustees meeting for example. High power and decision making personnel would be able to see where the institution's money is being spent as if they are already standing in the finished building.

5.2 BIM for Construction

The WPI facilities management team utilizes many software systems to ensure the campus's buildings to operate efficiently, to remain safe, in order, and to be fully functional. In addition to Schooldude, the Computer Maintenance Management System (CMMS) used by the facilities management department the FM team also uses a system known as WebCTRL offered by AutomatedLogic. WebCTRL is a building automation system the gives the user the ability to fully understand operations, and analyze the results with various tools. It packages information that is needed for facilities management without help from a third party service. This information was obtained from Roger Griffin of WPI who is the Associate Director for Mechanical Services. (Griffin, 2016). Tools within the software include color coded floor plans, Built-in Fault Detection Diagnostics (FDD) and WebCTRL time-lapse. The colored floor plans convey building conditions to the user in a quick and easy to understand fashion. The purpose of the FDD tool is to measure, analyze, and compare comfort conditions against set points, helping balance comfort with efficiency. The time lapse tool allows for analyzing and troubleshooting up to 24 hours of past building operation.

Currently at WPI, the facilities management team utilizes all the tools offered by AutomatedLogic's "WebCTRL" system. For the system to operate effectively, each piece of equipment needs a certain amount of information integrated into the software. Currently, this integration process is on an as needed basis. The main use of the software is demand loading equipment for automatic shedding. The Fault Detection Diagnostic tool by WebCTRL is utilized by the maintenance team at WPI for this purpose. Essentially, the software is working to better match the demand for power with the supply. Additionally, the interoperable functions of WebCTRL are moving into lighting control.

Linking the time-lapse capability within WebCTRL to Schooldude appears to be a legitimate possibility within the next couple of upgrades from the Schooldude software. This would be extremely useful for the WPI facilities management staff. For example, if a light in a WPI academic building burns out, the WebCTRL software will record this failure with assistance from the time-lapse tool. With interoperability between Schooldude and WebCTRL, this information can be generated into a work order within the Schooldude software. The integration of these two software has potential to save the facilities management team considerable time and effort in the future. This information gathering and collaboration must be done during the construction phase to better pass along to facilities during and after the project.

The role that BIM may be able to play with Schooldude and WebCTRL is that since Schooldude and WebCTRL will be able to be linked soon, a Revit model may be able to be incorporated with these two programs as well. Since WebCTL will be able to record such failures as a broken lightbulb, then automatically pass that information off to Schooldude and create a work order, one step further would be to have the 3D model appear as well and show the exact location of the issue. With all of these technologies linked under one umbrella, would allow for easier quicker solutions to facilities problems because WebCTRL automatically records a problem, Schooldude then creates the work order, and the BIM 3D model would show the exact location of the problem.

5.2.1 4D and 5D BIM

4D and 5D modeling is used to show the development of the cost and schedule linked to the 3D model. In a 4D model, the schedule is attached to the 3D model and can simulate the building being built with the corresponding times that were created in the original CPM schedule. The 5D model takes this one step further and links the costs associated with the items that are being built in the simulation. The 4D and 5D modeling is a very good representation to show where a project should be according to the original schedule. This model can then be compared to the actual work done on a project to determine if the project is on schedule and on budget. The 5D model can also go into great detail to show the percent complete of costs for specific items like concrete. Comparing a 5D model to actual progress of a project can show that the project is two days behind the original schedule, is $20,000 over budget, and has a percent complete of concrete of 59% and it should be at 65% in terms of cost. This information allows for earned value analysis to be conducted on the project's progress. Site logistics can also be modeled in 4D showing how trucks, cranes, and other large equipment enter and exit the site.

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The side by side images in Figures 12 and 13 represent the Foisie Innovation Studio in the

Figure 12 Actual Project Progress as Taken by Surveillance Camera

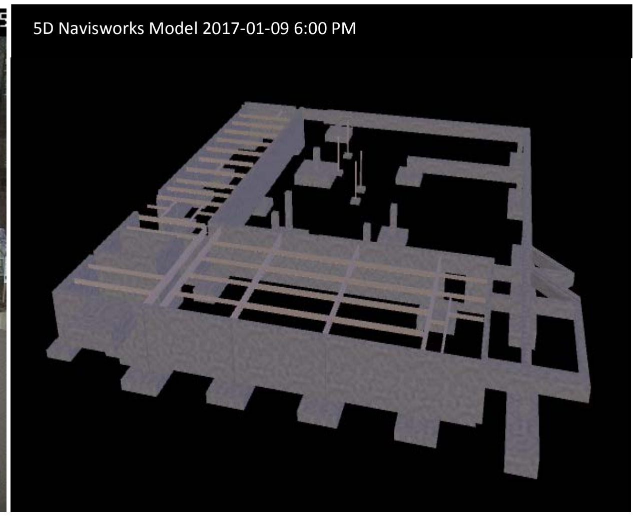

Figure 13 Progress Modeled in a 5D Navisworks Model

early stages of construction. The two images present a view of the construction from the same point in construction progression. The cast in place concrete foundation, and first floor steel are completely installed, the floor beams over the basement space are also completely installed and metal decking on top of these beams starts to be placed. Although the two images display the same phase of construction, they come from separate sources. The image on the left comes from a webcam on the top of Harrington Auditorium on the WPI campus. This particular webcam photo was taken on January 12, 2017. The image on the right was generated by a 5D model through the software Navisworks. The 5D model tracked the 3 dimensional progression of the building in correlation with schedule and cost. This particular image is a representation of what the building was projected to look like as of January 9, 2017 according to Shawmut Design and Construction's task schedule updated in October, 2016. These visual representations of the construction project provide a clear visual depiction of the project's progression. If properly utilized, they provide rich information to those interested about the status of the project's development at any time as the construction process progresses

In October of 2016, WPI administration expressed to Shawmut they would like to receive monthly reports of the project. The reports would serve as information to the general WPI community and assurance to the university's president and board of trustees that their money is properly invested. The use of building information modeling to provide such information and assurance to the campus was not utilized in these reports. However, the visual representations above would have potentially given the campus community what they were looking for. The 3D visual representation, in tandem with the date of the progression provides a thorough 4D progress report of the project.

This report method has the potential to be taken one step further if the owner is not satisfied with the 4D report, and is looking for more information. By combining the 4D model with the cost, a more informational description can be generated. Such a report would require the creation of a 5D model that breaks down the project's cost of material, labor, and equipment per day. This information would allow for a comparison of the actual cost of the building at a given point in the project to the initial projected cost at that corresponding date. An assessment of such detail provides complete transparency to those who are interested in the progression of the project.

As a deliverable of this MQP report, a PDF document was created to display before and after images, along with dates for the various activities of Foisie. This was created as an example as to how BIM can assist with the visualization of how the project is being completed and to track the progress and completion of the project as well as coordination of all activities necessary to complete the project from beginning to end. The document shows start and end dates as well as the Gantt chart for activities such as A and A1 footings. There is a link associated with each activity that jumps to the unique section where the before and after pictures can be seen. An example can be seen in Figure 14. These before and after picture show that the west wing foundation walls were started on November 21, 2016 and were completed December 22, 2016.

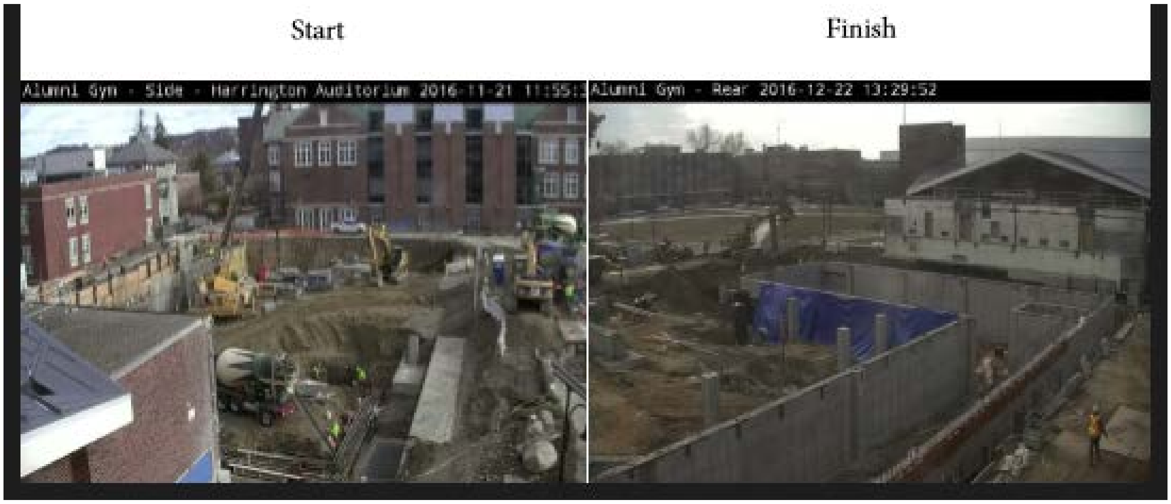

Figure 14 Tracking Project Progress Pictures

The searchable pdf that contains all of the before and after pictures is attached in Appendix K.

5.3 BIM for Facilities Management

One of the major objectives of the design and construction of the Foisie Innovation Studio was to incorporate the use of BIM technology to coordinate the creation, maintenance and eventual delivery of facilities management information. There were three major meetings where the major players of the project discussed what specific information WPI was looking and how this information was going to be created, maintained and handed over to WPI.

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A flow chart describing the collaboration between team members on the facilities management issue can be seen in Figure 15. This flowchart describes who was involved in certain processes along the way to the final FM integration design. Some members, such as the designer Gensler, was not a part of all of the meetings, but played a big role near the end of the

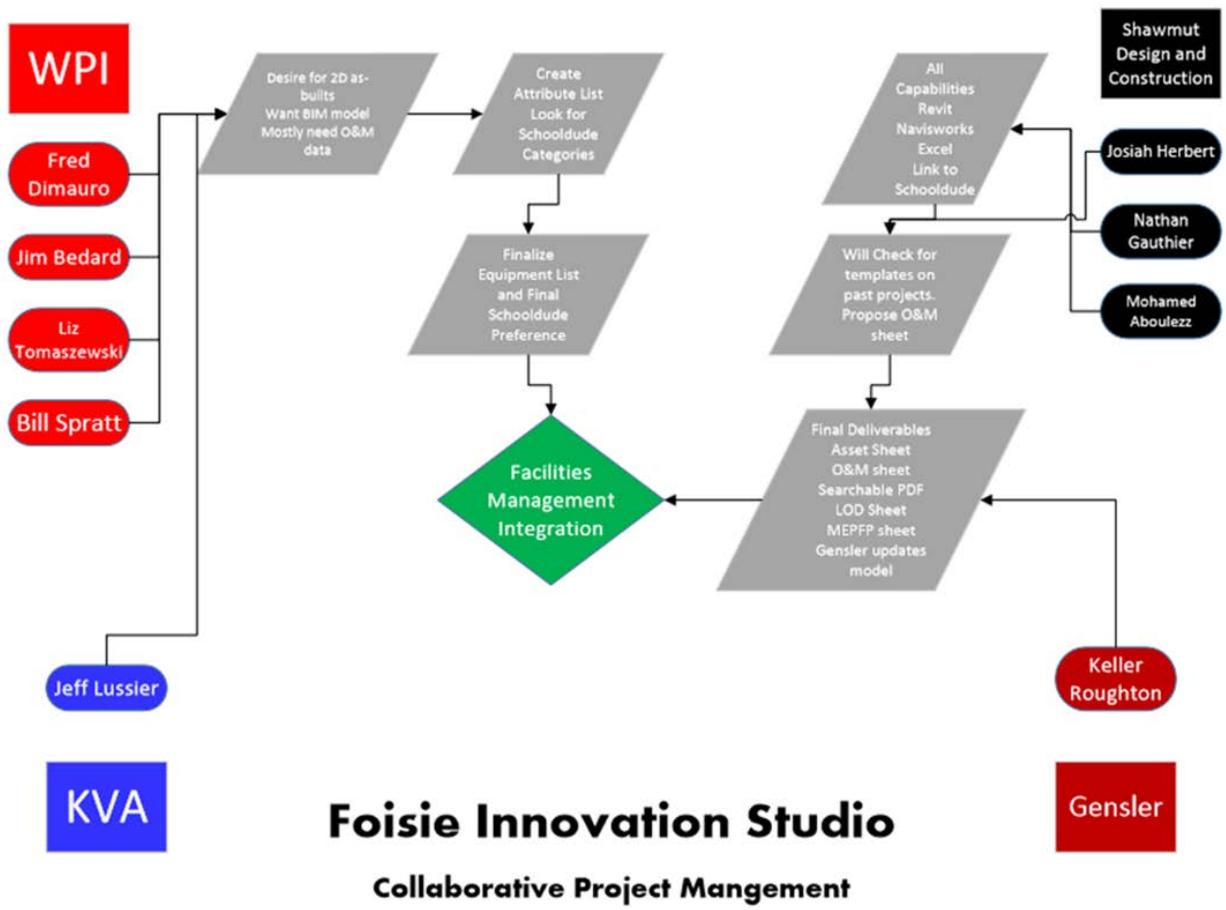

Figure 15 Facilities Management Collaboration Flow Chart

discussions. The flowchart also describes how ideas and processes developed over time through multiple meetings.

The first meeting was held on 9/20/16 and it was the first time that WPI expressed their interest in the use of BIM for this FM integration. This meeting was a preliminary one and discussions of general type took place. At that time no specific deliverables were established during the meeting. WPI's general expectation was that all of the FM related information could be done through the BIM model and given to them that way. WPI made a concern that they would only use that model if there was to be future work done on Foisie. WPI made it clear to Shawmut that they had not given consideration in using the BIM model and related information in preventative maintenance because they will get too many work orders flooding their CMMS software, Schooldude. WPI also raised their concern that the maintenance workers will not know how to use BIM-based software such as Revit or Navisworks in order to locate equipment, such as a boiler, to work on. The facilities workers at WPI are accustomed to using paper 2D drawings for reference. This led WPI to ask if there is a way that the BIM model or associated information could be linked directly to the school's Schooldude account. At the end of this meeting it was still unclear who would keep updating the BIM model and what exact information was going to be sought out from the contractor through its subcontractors.

The second FM integration meeting was held on 10/20/16. At that meeting, WPI and Shawmut came to agreements that certain attributes and categories of the building objects in the model of interest to facilities management needed to be identified so the subcontractors would provide this information through their shop drawings and samples. This meeting was successful as WPI and Shawmut both had identified specific action items for after the meeting. WPI (Bill Spratt and Jim Bedard) were going to check Schooldude and look through the construction drawings to determine which categories they would like to see from subs that can be entered into Schooldude. Shawmut was going to check and see if they had any templates that were already in place so that they do not have to start from scratch with regards to the categories and language to be used in contracts. Shawmut also noted that they would take full responsibility in terms of making sure all the information that WPI is seeking was obtained from the subcontractors.

The third and final FM integration meeting was on 10/25/16. WPI created a preliminary list of the equipment and information that they were looking for from the subcontractors. These items included large equipment such as air handling units or chillers, mostly what is found in the mechanical schedules from the plans. At the end of the meeting it was decided that WPI was going to create a complete list of the categories they want in Schooldude and give it to Shawmut. If Schooldude has a template it will be used, but if not Shawmut will make their own template. Once the list and template was created, Shawmut will distribute it to the subcontractors on the job and create contractual language so the subs must submit their info in such a way to be incorporated into the as-builts submitted by the end of the job by the construction manager in the form of a spreadsheet. The complete list of items at the end of the job, would be entered manually by WPI staff into Schooldude. Other information that WPI wanted included was a searchable PDF document to be linked into Schooldude so maintenance workers can pull up floor plans and elevations of a building to locate equipment and information.

There were talks throughout the meetings concerning who was going to keep updating the BIM model throughout the project. After a few meetings it was proposed to Gensler that they should be the ones to continuously update the model because they will be the ones updating it throughout the project as design modifications were made. Gensler agreed that they will periodically update the model, but only for major changes. Insignificant changes such as a light switch being moved an inch to the left will not be their responsibility and these should be reflected in the drawings and specifications submitted by the construction manager at the end of the project.

On 11/21/16 Shawmut proposed various deliverables to WPI for facilities management for the lifecycle of the Foisie Innovation Studio. One of the included deliverables is a two part document that describes the level of detail for MEPFP trade subs modeled elements. The systems that Shawmut included to have specific levels of detail for the as-built model include, sheet metal, HVAC piping, plumbing, electrical systems, fire protection systems, and control systems. Going into greater detail into those systems Shawmut included descriptions as to what was to be included. For HVAC piping for example, included elements will be pipe racks, support structures, hangers, valves, and much more. Appendix D describes the level of detail (LOD) for how systems will be modeled and transferred to WPI. These LOD range from LOD 100 to LOD 500. Architectural and structural models will be at LOD 300 and MEPFPs will be at LOD 350 after coordination and LOD 400 after construction. All of these are to be modeled in 3D. The MEPFP subcontractor requirements can be seen in Appendix E.

Along with the level of detail specifications, Shawmut also provided two versions of how equipment sheets can be created to convey important information in an easy to read format. One equipment data sheet is for operation and maintenance data and the other is for a sign that will be affixed to each piece of equipment. The example they used was an air handling unit and the one page document described manufacturer information as well as technical information like fan and motor speeds, and cooling and heating temperatures. This technical information will be attached to pieces of equipment in the actual building. Another document describes the subcontractor's information as well as warranty and preventative maintenance information. This O&M "cheat sheet" describes how often to inspect certain parts of the AHU and how to order spare parts. Both documents will be presented to the subcontractors to fill out at the end of their respective work. The asset sign for equipment can be seen in Appendix F and the operation and maintenance cheat sheet can be seen in Appendix G.

Shawmut also included the Schooldude categories from WPI's CMMS and described who was responsible for the various categories listed in the program. The Schooldude categories are also defined in a spreadsheet form that will be used as an important tool for the information gathered from subs and placed into Schooldude. This can be found in Appendix H. It is interesting to note here that Shawmut and the MQP team both worked to develop a list of the important categories that needed to be gathered for equipment in Foisie and be entered into Schooldude. The MQP team and Shawmut devised identical lists of the important categories that are shown in Appendix H.

For the Foisie Innovation Studio, the current standing for the information that facilities management is going to receive conforms to the way that WPI has been conducting their information handover from past buildings consistent with requirements of Schooldude which is the CMMS that WPI uses.

More could have been done during the facilities management meetings to have a more involved BIM based method. Key personnel such as Roger Griffin could have been incorporated at the beginning of the discussion to perhaps devise a method of creating 3D models of the MEP's. By doing so, a design could be created in a BIM software where the as-builts could be placed, along with the information that accompanies the equipment and other items in the building. WPI elected to have the information sheets as described earlier and enter them manually into the Schooldude program. By having all of the items, building elements, accompanying information and much more in one BIM location, time and effort could be saved by simply referring to one program for the information without having to manually input the information from the start. This would allow for very specific objects in the building to be seen in various views such as 3D and 2D elevations to pinpoint their location in the actual building.

This process relates to the previous sections on having a designated “WPI BIM position” or a student that works under someone with the title of “BIM student”. This full time job or student worker would be able to assist or run the BIM portion of all new projects that WPI undertakes. By having this better defined BIM role on campus, this individual would be part of the facilities staff. They would be in charge of future handover processes of future buildings and be able to create a comprehensive list of categories such as the ones from Schooldude.

This process of having all of the necessary information for WPI facilities in a model that can be searched and manipulated would be a great tool for maintaining the building throughout its lifecycle. WPI could start this process with the Foisie Innovation Studio and learn the pros and cons that result from the process. This could allow for WPI to have 3D models of future buildings in one program with all of the necessary information for facilities as well as other personnel.

6.0 Conclusion

In May of 2016, the demolition of Alumni Gym began and started to make way for the new Foisie Innovation Studio and Messenger Residence Hall. The Foisie Innovation studio is going to be a 77,760 square foot dual classroom and residence hall. The new building will be completed in the Fall of 2018 and feature a large maker space, café, and feature wall with auditorium style seating.

This report took an in depth look at the role of BIM in supporting a collaborative approach for design and construction at the Foisie Innovation Studio. Current practices were reviewed of how building contracts and project delivery styles are conducted. The collaborative process in which the owner, consultant, architect, construction manager, and more work as a team and work towards the same common goals is becoming a more widely used method in the construction industry. An in depth analysis was conducted to illustrate how the collaborations among the various project members was used to solve issues and various tasks. Some of these were highlighted in the active learning classrooms discussions (Section 4.1.4) and the facilities management collaborations (Section 5.3). Flowcharts were designed to illustrate the continuing iterations of how ideas changed and developed with the collaborations.

The final deliverables of this project consisted of suggesting an approach supported with BIM technologies could be more greatly utilized to enhance the collaborative style of the Foisie project as well as future projects. A BIM Execution plan was designed along with suggesting various BIM tools that can be used in future projects to assist with design and presentations like virtual reality goggles. Other BIM ideas that were recommended was the notion of 4D and 5D modeling. These are great tools for tracking the progress of the actual schedule and budget with the planned schedule and project that was created at the beginning of the project. An image of the current progress and the planned progress that is shown in the Revit model can be compared to track percent complete of line items and other scheduling and cost implications.

Further work that could be conducted to build on this MQP report would be to further explore the proposed approach by continuing the research and its implementation, to the extent possible, until the construction of the Foisie Innovation Studio is finally completed. It is also suggested to apply and improve the approach hereon developed in the design and construction of future projects on the WPI campus. A BIM execution plan could be used to provide a groundwork for having BIM involved in a higher degree. One project idea may be to create a completely comprehensive BIM execution plan that WPI could use in all of its projects in the future. Investigation into a specific BIM personnel position as part of the WPI faculty could be conducted. This person would be the go to between for the owner and the AEC (Architect, Engineer, and Contractor) personnel. Another potential area of further project work would be into developing a new method for creating an all in one BIM experience for facilities management. The goal would be to use BIM technologies to create one location where all necessary information of a campus building would be provided for facilities management. This may consist of taking the Revit model of the building and placing the as-builts of almost all of the equipment that is placed in the building. This nearly 100% as-built model would then have the information associated with each piece of equipment. For example, selecting an air handling unit in the model would bring up a catalog with information regarding its operation and maintenance manual, warranty information, and more.

This MQP experience was an insightful look into the newer construction project style of full collaboration among the different members of the project. The collaborative design and construction aspect is interesting in how it brings people together for one common goal and its ability to solve issues, work on changes, and keep great organization quickly and efficiently. It is with great hope that the WPI community as well as the stakeholders involved in the Foisie Innovation Studio project can learn from this report and may it lead to further project work in the future.

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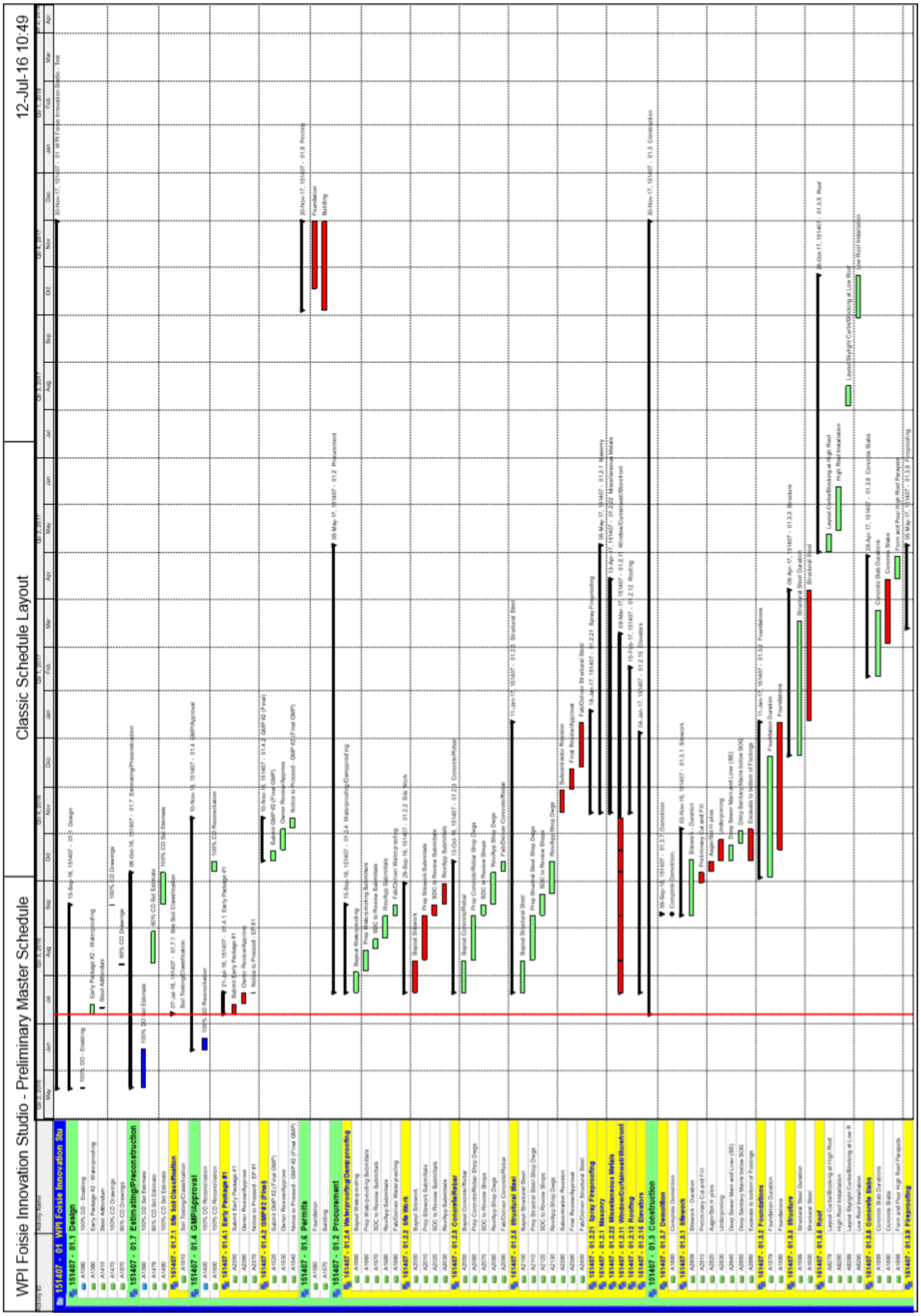
Appendix A Requisition

A	B	C	D	E	F	G	H	I		J	K
					WORK COMPLETED (F+G)						
ITEM NO.	DESCRIPTION OF WORK	ORIGINAL SOV	SOV CHANGES	SCHEDULED VALUE	FROM PREVIOUS APPLICATION	THIS PERIOD	MATERIAL PRESENTLY STORED	TOTAL COMPLETED AND STORED TO DATE	PER-% (I / E)	BALANCE TO FINISH	RETAINAGE
160894	**WPI - Foisie Innovation Studio**										
0100	General Conditions	2,943,990.00	0.00	2,943,990.00	280,380.00	140,190.00	0.00	420,570.00	14	2,523,420.00	21,028.52
0200	Project Requirements	1,167,626.00	176,800.00	1,344,426.00	2,722.50	5,552.26	0.00	8,274.76	1	1,336,151.24	413.75
0300	Concrete	1,900,901.00	0.00	1,900,901.00	75,584.00	506,250.00	0.00	581,834.00	31	1,319,067.00	29,091.70
0400	Masonry	1,613,510.00	0.00	1,613,510.00	0.00	0.00	0.00	0.00		1,613,510.00	0.00
0500	Structural Steel	1,937,980.00	0.00	1,937,980.00	0.00	20,400.00	0.00	20,400.00	1	1,917,580.00	1,020.00
0600	Misc Metals	594,250.00	0.00	594,250.00	0.00	0.00	0.00	0.00		594,250.00	0.00
0700	Rough Carpentry	373,195.00	-176,800.00	196,395.00	0.00	0.00	0.00	0.00		196,395.00	0.00
0800	Millwork	545,375.00	0.00	545,375.00	0.00	0.00	0.00	0.00		545,375.00	0.00
0900	Waterproofing	333,364.00	0.00	333,364.00	0.00	0.00	0.00	0.00		333,364.00	0.00
1000	Roofing	386,240.00	0.00	386,240.00	0.00	0.00	0.00	0.00		386,240.00	0.00
1100	Fireproofing	203,296.00	0.00	203,296.00	0.00	0.00	0.00	0.00		203,296.00	0.00
1200	Joint Sealants	65,010.00	0.00	65,010.00	0.00	0.00	0.00	0.00		65,010.00	0.00
1300	Doors, Frames & Hardware	331,475.00	0.00	331,475.00	0.00	0.00	0.00	0.00		331,475.00	0.00
1400	Special Doors	73,600.00	0.00	73,600.00	0.00	0.00	0.00	0.00		73,600.00	0.00
1500	Storefront	3,463,965.00	0.00	3,463,965.00	0.00	40,320.17	0.00	40,320.17	1	3,423,644.83	2,016.01
1600	Glazing	41,100.00	0.00	41,100.00	0.00	0.00	0.00	0.00		41,100.00	0.00
1700	Drywall	2,154,653.00	0.00	2,154,653.00	0.00	0.00	0.00	0.00		2,154,653.00	0.00
1800	Tile	123,204.00	0.00	123,204.00	0.00	0.00	0.00	0.00		123,204.00	0.00
1900	Acoustical Ceilings	131,920.00	0.00	131,920.00	0.00	0.00	0.00	0.00		131,920.00	0.00
2000	Carpet/Resilient Flooring	379,756.00	0.00	379,756.00	0.00	0.00	0.00	0.00		379,756.00	0.00
2100	Painting	303,845.00	0.00	303,845.00	0.00	0.00	0.00	0.00		303,845.00	0.00
2200	Specialties	192,110.00	0.00	192,110.00	0.00	0.00	0.00	0.00		192,110.00	0.00

A	B	C	D	E	F	G	H	I		J	K
ITEM NO.	DESCRIPTION OF WORK	ORIGINAL SOV	SOV CHANGES	SCHEDULED VALUE	WORK COMPLETED (F+G) FROM PREVIOUS APPLICATION	THIS PERIOD	MATERIAL PRESENTLY STORED	TOTAL COMPLETED AND STORED TO DATE	PER-% (I / E)	BALANCE TO FINISH	RETAINAGE
160894	**WPI - Foisie Innovation Studio**										
2300	Signage	55,540.00	0.00	55,540.00	0.00	0.00	0.00	0.00		55,540.00	0.00
2400	Equipment	165,188.00	0.00	165,188.00	0.00	0.00	0.00	0.00		165,188.00	0.00
2500	Window Treatment	150,602.00	0.00	150,602.00	0.00	0.00	0.00	0.00		150,602.00	0.00
2600	Elevator	657,800.00	0.00	657,800.00	271,000.00	6,504.00	0.00	277,504.00	42	380,296.00	13,875.20
2700	Fire Protection	386,356.00	0.00	386,356.00	0.00	0.00	0.00	0.00		386,356.00	0.00
2800	Plumbing	1,057,527.00	0.00	1,057,527.00	0.00	0.00	0.00	0.00		1,057,527.00	0.00
2900	HVAC	4,932,901.00	0.00	4,932,901.00	0.00	0.00	0.00	0.00		4,932,901.00	0.00
3000	Electric	3,460,944.00	0.00	3,460,944.00	0.00	0.00	0.00	0.00		3,460,944.00	0.00
3100	Earthwork	2,105,860.00	0.00	2,105,860.00	621,900.00	248,980.00	0.00	870,880.00	41	1,234,980.00	43,544.00
3200	Landscaping	1,164,013.00	0.00	1,164,013.00	0.00	0.00	0.00	0.00		1,164,013.00	0.00
3300	Concrete Finishing	185,807.00	0.00	185,807.00	0.00	0.00	0.00	0.00		185,807.00	0.00
3400	Sheetmetal Flashing	154,875.00	0.00	154,875.00	0.00	0.00	0.00	0.00		154,875.00	0.00
3500	Spray Acoustic Insulation	97,363.00	0.00	97,363.00	0.00	0.00	0.00	0.00		97,363.00	0.00
3600	Communications	308,965.00	0.00	308,965.00	0.00	0.00	0.00	0.00		308,965.00	0.00
3700	Security	90,000.00	0.00	90,000.00	0.00	0.00	0.00	0.00		90,000.00	0.00
3800	Temp Heat and Food Equip Allowance	295,000.00	0.00	295,000.00	0.00	0.00	0.00	0.00		295,000.00	0.00
3900	Permits	379,820.00	0.00	379,820.00	114,204.00	0.00	0.00	114,204.00	30	265,616.00	5,710.20
4000	G.L. Insurance	452,331.00	0.00	452,331.00	45,233.10	16,871.13	0.00	62,104.23	14	390,226.77	3,105.21
4100	Performance & Payment Bonds	261,966.00	0.00	261,966.00	0.00	0.00	0.00	0.00		261,966.00	0.00
4200	Construction Contingency	1,090,011.00	0.00	1,090,011.00	0.00	0.00	0.00	0.00		1,090,011.00	0.00
4300	Fee	972,435.00	0.00	972,435.00	97,243.50	29,173.05	0.00	126,416.55	13	846,018.45	6,320.83

Appendix B Master Schedule



Appendix C Summary of Meetings

Preconstruction/Design Meetings					
#	Meeting Overview	Meeting Date	Meeting Time	# of Items	Major Topics
1	Bi Weekly Design Meeting	3/15/2016	10:00am-12:00pm	11	HVAC Delivery System
2	Bi Weekly Design Meeting	3/29/2016	10:00am-12:00pm	24	Electrical System
3	Bi Weekly Design Meeting	4/12/2016	10:00am-12:00pm	24	Plumbing
4	Bi Weekly Design Meeting	4/26/2016	10:00am-12:00pm	14	Plumbing & Grotesques
6	Bi Weekly Design Meeting	5/24/2016	10:00am-12:00pm	11	Utility Schedule
Curtainwall Design Assist Meetings					
#	Meeting Overview	Meeting Date	Meeting Time	# of Items	Major Topics
1	Weekly Curtainwall Design Assist Meeting	9/6/2016	10:00am-12:00pm	8	Structural Silicone Joints
2	Weekly Curtainwall Design Assist Meeting	9/13/2016	10:00am-12:00pm	12	Curtainwall System Selection
3	Weekly Curtainwall Design Assist Meeting	9/20/2016	10:00am-12:00pm	5	Curtainwall System Selection
4	Weekly Curtainwall Design Assist Meeting	9/27/2016	10:00am-12:00pm	6	Curtainwall System Selection
Construction Meetings					
#	Meeting Overview	Meeting Date	Meeting Time	# of Items	Major Topics
20	Weekly Construction Meeting	8/30/2016	1:00pm-3:00pm	26	Demo/Abatement
21	Weekly Construction Meeting	9/6/2016	1:00pm-3:00pm	23	Security Meeting
22	Weekly Construction Meeting	9/13/2016	1:00pm-3:00pm	28	Demo/Abatement & Plumbing Variance
23	Weekly Construction Meeting	9/20/2016	1:00pm-3:00pm	29	Construction Schedule
24	Weekly Construction Meeting	9/27/2016	1:00pm-3:00pm	25	FM Integration
25	Weekly Construction Meeting	10/4/2016	1:00pm-3:00pm	24	Precast Flooring for "Link"
26	Weekly Construction Meeting	10/18/2016	1:00pm-3:00pm	20	Feauture Wall
27	Weekly Construction Meeting	10/25/2016	1:00pm-3:00pm	19	Foudnation Waterproofing
28	Weekly Construction Meeting	11/1/2016	1:00pm-3:00pm	16	Classroom Density
29	Weekly Construction Meeting	11/8/2016	1:00pm-3:00pm	17	Graphics Piece
30	Weekly Construction Meeting	11/15/2016	1:00pm-3:00pm	16	Construction Schedule
31	Weekly Construction Meeting	11/29/2016	1:00pm-3:00pm	15	Change Management
32	Weekly Construction Meeting	12/6/2016	1:00pm-3:00pm	14	Classroom Density
33	Weekly Construction Meeting	12/13/2016	1:00pm-3:00pm	12	Classroom Density
34	Weekly Construction Meeting	12/20/2016	1:00pm-3:00pm	13	Topping Off Ceremony
35	Weekly Construction Meeting	1/3/2017	1:00pm-3:00pm	12	Buyout/Budget Comparison
36	Weekly Construction Meeting	1/10/2017	1:00pm-3:00pm	12	HVAC Subcontractors
37	Weekly Construction Meeting	1/17/2017	1:00pm-3:00pm	13	Northwest Corner Watermain
38	Weekly Construction Meeting	1/24/2017	1:00pm-3:00pm	17	Blackened Steel vs Painting
39	Weekly Construction Meeting	1/31/2017	1:00pm-3:00pm	19	Café
40	Weekly Construction Meeting	2/7/2017	1:00pm-3:00pm	18	Northwest Corner Watermain
41	Weekly Construction Meeting	2/14/2017	1:00pm-3:00pm	18	Exterior Brick Design
42	Weekly Construction Meeting	2/21/2027	1:00pm-3:00pm	17	Topping Off Ceremony
43	Weekly Construction Meeting	2/28/2017	1:00pm-3:00pm	16	Café
Facilities Management Integration					
#	Meeting Overview	Meeting Date	Meeting Time	# of Items	Major Topics
1	FM Integration	9/20/2016	1:00pm-3:00pm	1	Schooldude Integration
2	FM Integration	10/20/2016	1:00pm-3:00pm	1	List of Equipment from WPI for as-builts
3	FM Integration	10/25/2016	1:00pm-3:00pm	1	Categories, Asset Sheets, LOD

Appendix D Level of Detail Definitions

SHAWMUT
Design and Construction

APPENDIX B – Level of Detail (LOD) Definitions

LOD 100 The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

LOD 200 The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

LOD 300 The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element. **– All Models here after design. Architectural and Structural models should still be here but incorporate SK's and ASI's after construction.**

LOD 350 The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element. **– MEPFP Models will be here after coordination.**

LOD 400 The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element. **– MEPFP Models will be here after construction.**

LOD 500 The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

Appendix E As Built Level of Detail

Proposed BIM As-Built Level of Detail

APPENDIX A – MEPFP Trade Subs Modeled Elements

Sheet Metal

- All HVAC systems
- Ductwork
- Diffusers
- Flex duct
- VAV boxes
- Required clearances
- Space for maintenance
- Air Handler Units
- Fans
- Pumps
- Tank
- Control boxes
- Access panels
- Heat exchanges
- Hangers
- Seismic supports
- Other support systems
- Anything included on schedule
- All components relevant for space coordination

HVAC Piping

- All HVAC piping
- Pipe racks
- Support structures
- Hangers
- Valves
- Diverters
- Distribution systems
- Equipment
- Insulation
- Equipment Connectors
- Maintenance clearances
- Anything included on schedule
- All components relevant for space coordination

Plumbing

- All plumbing work
- Pipe
- Pipe racks
- Support structures
- Hangers
- Valves
- Diverters
- Distribution systems
- Equipment
- Medical gas systems
- Gas tanks
- Rain water leaders
- Pressure and drainage pipe
- Insulation
- Equipment connectors
- Maintenance clearances
- Anything included on schedule
- All components relevant for space coordination

Electrical Systems

- All electrical work
- Conduit in racks carrying more than 3 conduits
- Light fixtures
- Panel boxes
- Required clearance
- Ceiling plane
- Conduit 1" dia. and greater
- Groupings of conduit 1" and greater cross-section
- Conduit exposed to public view

- Anything included on schedule
- All components relevant for space coordination

Fire Protection Systems

- All fire protection
- Pipes
- Branch connections
- Drops
- Sprinkler heads
- Valves
- Fire pumps
- Panels
- Maintenance clearances
- Hangers
- Supports
- Anything included on schedule
- All components relevant for space coordination

Control Systems

- All control systems
- Conduit in conduit racks carrying more than 3 conduits
- Panel boxes
- Required clearance
- Conduit 1" dia. and greater
- Groupings of conduit 1" and greater cross-section
- Conduit exposed to public view
- Anything included on schedule
- All components relevant for space coordination

Appendix F Asset Sign

Foisie Innovation Studio

Air Handling Unit - "AHU-8"

Equipment No.	EQ003770	**Bar Code:**	NA
Location:	Mechanical Room (Room Number?)		
Serves:	Small Macs and Racquet Ball		
Make:	Custom?	**Model:**	Custom
Serial No:	NA	**Warranty:**	October 17, 2017

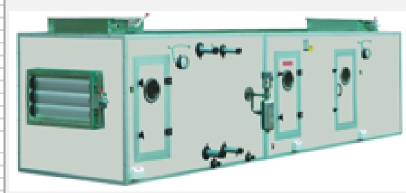
Fan & Motor:	• 30,000 CFM Max	• 7,500 CFM Min OA
	• Airfoil Type	• 1.75" WC ESP
	• 30 HP	• 460 Volt / 3 Phase
Cooling:	• Chilled Water	• 1,110 kBTU/Hr (92.5 Ton)
	• 79/64.9°F EAT (DB/WB)	• 53/52.9°F LAT (DB/WB)
	• 45°F EWT / 55°F LWT	• 217 GPM CW
Heating:	• Hot Water	• 1,145 kBTU/Hr
	• 51°F EAT / 85°F LAT	• 54 GPM HW
	• 200°F EWT / 160°F LWT	• 54 GPM HW
Parts:	• BELT?	
	• Filter 1?	
Controls:	Describe the controls for this unit...	

Appendix G Operation and Maintenance Cheat Sheet

SHAWMUT
Design and Construction

Air Handling Unit
Unit Name

AHU - 1
Unit Tag



Product Information*

Make:	Buffalo Air Handling
Model:	BF2AI-C3
Serial:	130147-01
Install / Startup Date:	Feb. 1, 2016
Warranty Expiration:	Feb. 1, 2017

**See nameplate for additional information*

Equipment-Specific Attributes

CFM:	10,000
Fan Count:	2
Other:	Enthalpy Wheel

Factory Representative

Name:	Emerson Swan
Contact:	John MacBlane
Phone:	(781) 986-2555
Email:	jmacblane@emersonswan.co

Sub-Contractor

Name:	Arden Engineering
Contact:	Harold Sloane
Phone:	(401) 727-3500
Email:	hsloane@ardeneng.com

Page 1

Preventative Maintenance*

Task	Freq.	Task	Freq.
Inspect rotating parts	Quarterly	Lubricate motor bearings	See O&M
Check fan bearing alignements	Quarterly	Wash eliminator plates	Annually
Lubricate fan bearings	See O&M	Repair / replace cabinet insulation	As Needed
Clean dampers	As Needed	Replace dirty filters	As Needed
Clean dirt from fan and housing	As Needed		
Replace worn V-belts	As Needed	*See O&M m	

Spare Parts

American Air Filter (358-35-06A-12A)

Client: CLIENT

Project:

Shawmut Design and Construction - (617) 6

Maintenance Checklist

Table 61. Maintenance Checklist

Frequency	Maintenance
Every week	• Observe unit weekly for any change in running condition and unusual noise.
Every month	• Clean or replace air filters if clogged or dirty. • Inspect and clean the main and auxiliary drain pans.
Every three to six months	• Manually rotate the fan wheel to check for obstructions in the housing or interference with fan blades. Remove any obstructions and debris. • Check motor bracket torque. • Inspect coils for dirt build-up. Clean fins if airflow is clogged.
Every year	• Check and tighten all set screws, bolts, locking collars and sheaves. • Inspect the unit casing for chips corrosion. If damage is found, clean and repaint. • Clean the fan wheels. Remove any rust from the shaft with an emery cloth and recoat with L.P.S. 3 or equivalent. • Rotate the fan wheel and check for obstructions. The wheel should not rub. Adjust the center if necessary. • Inspect and clean drain pans. • Check damper linkages, fan set screws, and blade adjustment. Clean, but do not lubricate, the nylon damper rod bushings. • Inspect, clean, and tighten all electrical connections and wiring. • Inspect the strainer option for debris trapped in the filter screen. • Examine flex connections for cracks or leaks. Repair or replace damaged material.

Air Filters

⚠WARNING

Rotating Components!

The following procedure involves working with rotating components. Disconnect all electric power, including remote disconnects before servicing. Follow proper lockout/ tagout procedures to ensure the power can not be inadvertently energized. Secure rotor to ensure rotor cannot freewheel. Failure to secure rotor or disconnect power before servicing could result in rotating components cutting and slashing technician which could result in death or serious injury.

Change or clean air filters at least twice a year. Filters require more frequent care under high load or dirty air conditions since a clogged filter reduces airflow. Table 1 and Table 2 on page 16 lists filter size and quantity by unit size. Throwaway and pleated media filters are available for all units.

NOTICE:

Replace All Panels and Filters Properly!

All unit panels and filters must be in place prior to unit startup. Failure to have panels and filters in place could result in equipment damage.

Remove the front panel of the vertical recessed unit and open the bottom panel door of the horizontal cabinet and

Appendix H As-Built Category List

Column	Field Description	Responsibility	Notes
A	ITEM NUMBER	WPI	
B	CLASSIFICATION	WPI	
C	TYPE	WPI	
D	DESCRIPTION	Shawmut	Develop a standard description nomenclature, i.e., AHU-1-FIS
E	MANUFACTURER	Shawmut	List name of manufacturer
F	SUPPLIER	Shawmut	List name of supplier
G	DATE PURCHASED	NA	
H	ORIGINAL COST	NA	
I	LOCATION	Shawmut	Use standard location nomenclature which WPI will define
J	BUILDING	NA	
K	AREA	Shawmut	Use standard location nomenclature which WPI will define
L	AREA NUMBER	Shawmut	Use standard location nomenclature which WPI will define
M	TAG NUMBER	WPI	
N	MODEL NUMBER	Shawmut	Model number
O	SERIAL NUMBER	Shawmut	Serial number
P	OUT OF SERVICE – BEGIN	NA	
Q	OUT OF SERVICE – END	NA	
R	DATE PLACED	Shawmut	Date installed
S	DATE REMOVED	NA	
T	WARRANTY EXPIRES	Shawmut	Warranty expiration date
U	LIFE EXPENTANCY UNIT	Shawmut	Provide number of hours
V	LIFE EXPENTANCY	Shawmut	Provide number of years
W	NOTES	Shawmut	Provide information as applicable: amps, voltage, phase, belts, filters, panel number, breaker number
X	INCLUDE NOTES	NA	yes

Appendix I Color Coded BIM Execution Plan

BIM Execution Plan

Created by: Christian Doskocil & Michael Vaitkunas
March 3rd, 2017
As part of "The Role of BIM in a Collaborative Approach for Design and Construction at the Foisie Innovation Studio" MQP

Color Coded Copy

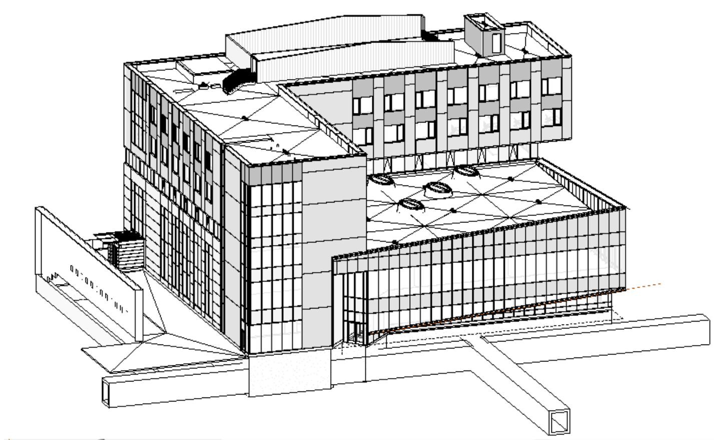


Table of Contents

Contents

1.0 BIM Execution Plan Overview

This BIM Execution plan is to contractually create a plan for utilizing BIM technologies within the specific scope of work. The plan is to create streamlined collaboration among project teams and their members as well as foster an ease of communication. The plan is to be a guide for what BIM technologies are to be used, how they are to be used, and how information is shared. The document is utilized to create meetings, settle grievances, as well as creating changes to this document.

(This color coded document illustrates what features of this plan were actually used in the Foisie Innovation Studio Project, and what is recommended for future projects.)

Green text depicts items that were used by the project team members on the Foisie Innovation Studio.

Red text depicts items that should have been implemented on this project and used in future projects.

Blue text depicts items that were used in the Foisie Innovation Studio project, but did not use BIM to achieve them.

2.0 Agreement

This agreement is made this _____ day of _______ in the year _______ by and between the

OWNER ___ Worcester Polytechnic Institute ____________________

and the

CONSTRUCTION MANAGER ___ Shawmut Design and Construction ___

and the

ARCHITECT ___ Gensler ___

and the

CONSULTANT ___ KVAssociates ___

3.0 Project Overview

This BIM Execution Plan is for the project ___ Foisie Innovation Studio ___

Located in ___ Worcester Massachusetts ___

With these specific BIM related milestone dates…

Schematic Design ____________________ Design Documents_____________________

Construction Documents___________ Completed 3D Model___________________

Other_____________________________

*Additional milestones may be set forth by the project teams.

4.0 Key People and Contact Information

This section is to provide information of the members of the project teams that will be taking part in the BIM collaboration. The individuals that are listed in this section will be legally bound by this document.

Name	Company	Phone Number	Email Address
Mohamed Aboulezz	Shawmut		
Nathan Gauthier	Shawmut		
Bill Spartt	WPI		
Jim Bedard	WPI		
Liz Tomaszewski	WPI		
Mike Vaitkunas & Christian Doskocil	WPI		
Keller Roughton	Gensler		

5.0 BIM Use

The BIM use section is used to define the specific tasks in which BIM is being implemented to accomplish. The project members shall herby agree to and collaborate to carry out the specific tasks selected and provide descriptions of final deliverables as can documented in section 3.0

(Please circle which uses of BIM will be appropriate and agreed upon for this project.)

1. Building (Preventative) Maintenance Scheduling (Facilities Management)

2. Building System Analysis

3. Asset Management (Equipment)

4. Space Management and Tracking

5. Disaster Planning

6. Record Modeling

7. Site Utilization Planning

8. Construction System Design

9. Digital Fabrication

10. 3D Control and Planning

11. 3D Coordination

12. Design Authoring

13. Engineering Analysis

14. Sustainability (LEED) Evaluation

15. Code Validation

16. Site Analysis

17. Design Reviews

18. Phase Planning (4D Modeling)

19. Cost Estimation

20. Existing Conditions Modeling

21. MEP Coordination

22.

Other_______________________

____

____

6.0 BIM Meetings/Coordination

The BIM meetings and coordination system is to define the continuous meetings that are to be held when discussing, creating, or changing BIM related project elements. Various specialty meetings and non-critical path milestones may also be documented.

Meeting Name	Description	Date(s)
BIM Execution Plan Kickoff	Agree to, make changes, and sign this document.	
Weekly BIM Meeting	Document BIM related changes and major information.	
BIM Subcontactor/CM Meetings	Supply Subcontractors with Sub BIM Execution Plan for agreement.	
3D Model Update	How often the as-built model will be updated throughout the project.	Whenever as-builts from subs are acquired
4D Model Creation	When the 4D model will be completed and demonstrated to necessary personnel.	

6.1 Communication

Communication guidelines will be set forth and agreed to by the project members. The communication techniques will be a mix of in person and electronic methods.

1. In person communication will be done through the various meetings that were described in Section 6.0

2. Phone communication and conference calls (unable to attend meetings) will be conducted via the information described in Section 4.0

3. Electronic communication will be done via email as described in Section 4.0

4. Other means of communication through a specific construction management system ____ Procore __ will be utilized.

5. Meeting meetings will be distributed and used as means of communication to document past meetings as well as for reference.

7.0 BIM Applications and Hardware

The BIM applications and hardware section set guidelines for what BIM technologies are used and the level of sharing that is allowed for each. This section sets boundaries as well as to ensure all project members are well informed.

7.1 Software

The specific BIM software that will be used will be defined in this section and be agreed to by all party members by signing this document

1. Revit

2. Navisworks

3. Autocad Civil 3D

4. BIM 360 (any variation)

5. Other:_______________

7.2 Security and Sharing

This section provides guidelines for intra-team software usage and potential access that may be given from one team to another. Most agreements are broken into yes/no responses, and if a yes is selected, further instruction will follow.

If applicable, will specific BIM software be given to project members without said software? (Y/N). If yes,____

If applicable, will project members without access already be able to access cloud based services? (Y/N) If yes,_________________ ____ Procore ________________________________

For software and services that require login credentials, will the owning party grant administrative, guest, or any other variation of access to other project members? (Y/N)

If yes,_______ Procore ____

Will there be a specific naming convention for files that will be shared by project members? (Y/N). If yes,____

8.0 Additional BIM Tools

BIM tools are useful supplements to enhance the Building Information Modeling experience and can greatly influence designs.

Virtual Reality goggles will be used to assist with design or other aspects of the project. (Example: virtual reality goggles may be used to present renderings to key owner personnel or used for presentations) (Y/N) If yes, what type of technology will be used?___________________

What party will be responsible for this technology? _________ Shawmut Design and Construction _________

3D renderings will be used along with 2D drawings to gain insight and ideas about various design aspects. (Y/N) If yes, state the nature of frequency and request____

9.0 Additional Degrees of Modeling

Will 4D modeling be used to track the actual progress with the scheduled progress incorporated in the Revit model? (Y/N) If yes, what party is responsible ________________________________

How often will this be updated ____

Will a 5D model be created to track the schedule, as well as the cost associated with the project with respect to actual progress vs the scheduled design in the Revit model? (Y/N) If yes, what party is responsible ____

How often will this be updated ____

10.0 Subcontractors

The subcontractor section is to provide a ground work for what information will be required from subcontractors for the project. The guidelines will be agreed upon in this document, then prepared in the document (Subcontractor BIM Agreement) in Appendix A for distribution to the subcontractors. The requirements from the subcontractors will include required software, level of detail, and other special instructions.

The agreed upon software and file requirements from subcontractors for shop drawings will be accepted from the following applications, ____ Revit, Autocad Civil 3D, Autocad MEP ______

Will subcontractors have same BIM sharing rights as described in Section 7.2 (Y/N). If yes, it will described in the Subcontractor BIM Agreement document.

Will a specific level of detail (LOD) be described to subcontractors for BIM applications? (Y/N). If yes, will a standard LOD convention by use? (Y/N). If yes, the standard that will be used is____

If no, a custom LOD specification will be created by the project team and attached to the Subcontractor BIM Agreement document.

In the event that a subcontractor is selected based on bid price as well as reputation, but does not conform with the guidelines set forth in this section as put forth in the Subcontractor BIM Agreement, will an exception be made to use the subcontractor regardless due to financial and schedule considerations? (Y/N)

If yes, the project members whom signed this document are to draft a document for the criteria necessary in place of the Subcontractor BIM Agreement.

11.0 Deliverables

This section is to describe specific deliverables that will be completed throughout the project and mostly at project completion. The final deliverables will be described as who is responsible for the final deliverable, and who it is to be presented too.

Deliverable	Description	Responsible Party	End Recipient
Final Revit Model	Complete as-built 3D model	Architect	Owner
Facilities Management Integration	Equipment, O&M Data, Preventative Maintenance	Construction Manager	Owner

12.0 Settling Grievances

This section is to list out the steps to be taken if there are any disputes or issues that arise during the BIM collaboration process. The methods list a chronological order for how disputes should be settled.

1: The first step if there is a grievance is to try to work out the problem between the two or more project members that are involved. Compromises or some leeway can be given to be able to appease both sides or yield a satisfactory result.

2. If the immediate project members cannot come to a resolution than other project members and perhaps other project teams may need to step in to help with a solution. This method will need collaboration and giving and taking

3. If none of the project team members can come to an agreement than a third party arbitrator will need to be used to clear the dispute.

13.0 Changing or Adding to the BIM Execution Plan

This section is to outline how changes and additions can be made to this document to make sure that all aspects for BIM execution are covered by the project team members. If there is a change or addition to this document to be made then the project team must create an amendment and agree upon it based on the template in this section.

The project team proposes to change/add____

to the BIM Execution Plan.

The purpose of this amendment is to

____

____

The parties that will be involved in this amendment are (circle appropriate parties)

Owner Construction Manager Architect Consultant

The final deliverable(s) are to be presented from_____________ to ____________________

and consist of ____

14.0 Signatures

Upon signature of this document, all involved parties will be contractually and legally bound to this BIM Execution Plan. Only one signature per project team is needed to represent multiple people.

OWNER : Worcester Polytechnic Institute

Name: __________________________ Signature: _____________________________

CONSTRUCTION MANAGER :

Shawmut Design and Construction

Name: __________________________ Signature: _____________________________

ARCHITECT: Gensler

Name: __________________________ Signature: _____________________________

CONSULTANT: KVAssociates

Name: __________________________ Signature: _____________________________

Appendix A: Subcontractor Agreement

As a subcontractor about to take place in the project ___________________________________

Agrees to the statements made in this contract and is legally obligated to the terms unless otherwise specified by the parties involved.

1: BIM Technology Agreement

The subcontractor agrees to provide shop drawings and other relevant documents in the applications listed below, (please circle)

Revit   Navisworks   BIM 360   Autocad Civil 3D   Other _________________

The level of detail that will be provided in the shop drawings and other relevant documents will be
____

2. Data Relevant for Facilities Management

The subcontractor will provide the following data and information to be passed along to the owner for facilities management purposes and lifecycle of the project, (please circle)

Equipment   Warranty Information   Maintenance Requirements   Manufacturer

Original Cost   Owner's Manuals   Spare Parts   Equipment Specifications

Other ____

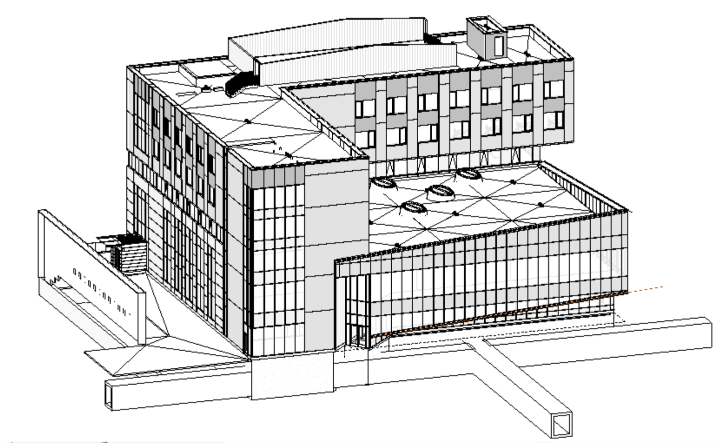
The manner in which the handover process of information from subcontractor to CM and owner will be through the BIM technology_____________________________

If conditions require information to be handed over in paper documents check box [ ]

Appendix J Workable BIM Execution Plan

BIM EXECUTION PLAN

Created by: Christian Doskocil & Michael Vaitkunas
March 3rd, 2017
As part of "The Role of BIM in a Collaborative Approach for Design and Construction at the Foisie Innovation Studio" MQP



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2.0 Agreement

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OWNER ____

and the

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and the

ARCHITECT____

and the

CONSULTANT____

3.0 Project Overview

This BIM Execution Plan is for the project______________________________________

Located in____

With these specific BIM related milestone dates…

Schematic Design ________________ Design Documents____________________

Construction Documents___________ Completed 3D Model__________________

Other___________________________

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(Please circle which uses of BIM will be appropriate and agreed upon for this project.)

1. Building (Preventative) Maintenance Scheduling (Facilities Management)

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8. Construction System Design

9. Digital Fabrication

10. 3D Control and Planning

11. 3D Coordination

12. Design Authoring

13. Engineering Analysis

14. Sustainability (LEED) Evaluation

15. Code Validation

16. Programming

17. Site Analysis

18. Design Reviews

19. Phase Planning (4D Modeling)

20. Cost Estimation

21. Existing Conditions Modeling

22. MEP Coordination

23.

Other______________________

____

____

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The project team proposes to change/add____

to the BIM Execution Plan.

The purpose of this amendment is to

____

____

The parties that will be involved in this amendment are (circle appropriate parties)

Owner   Construction Manager   Architect   Consultant

The final deliverable(s) are to be presented from_______________ to ________________________

and consist of ____

14.0 Signatures

Upon signature of this document, all involved parties will be contractually and legally bound to this BIM Execution Plan. Only one signature per project team is needed to represent multiple people.

OWNER

Name: __________________________   Signature: ______________________________

CONSTRUCTION MANAGER

Name: __________________________   Signature: ______________________________

ARCHITECT

Name: __________________________   Signature: ______________________________

CONSULTANT

Name: __________________________   Signature: ______________________________

Appendix A: Subcontractor Agreement

As a subcontractor about to take place in the project ______________________________________

Agrees to the statements made in this contract and is legally obligated to the terms unless otherwise specified by the parties involved.

1: BIM Technology Agreement

The subcontractor agrees to provide shop drawings and other relevant documents in the applications listed below, (please circle)

Revit   Navisworks   BIM 360   Autocad Civil 3D   Other __________________

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2. Data Relevant for Facilities Management

The subcontractor will provide the following data and information to be passed along to the owner for facilities management purposes and lifecycle of the project, (please circle)

Equipment   Warranty Information   Maintenance Requirements   Manufacturer

Original Cost   Owner's Manuals   Spare Parts   Equipment Specifications

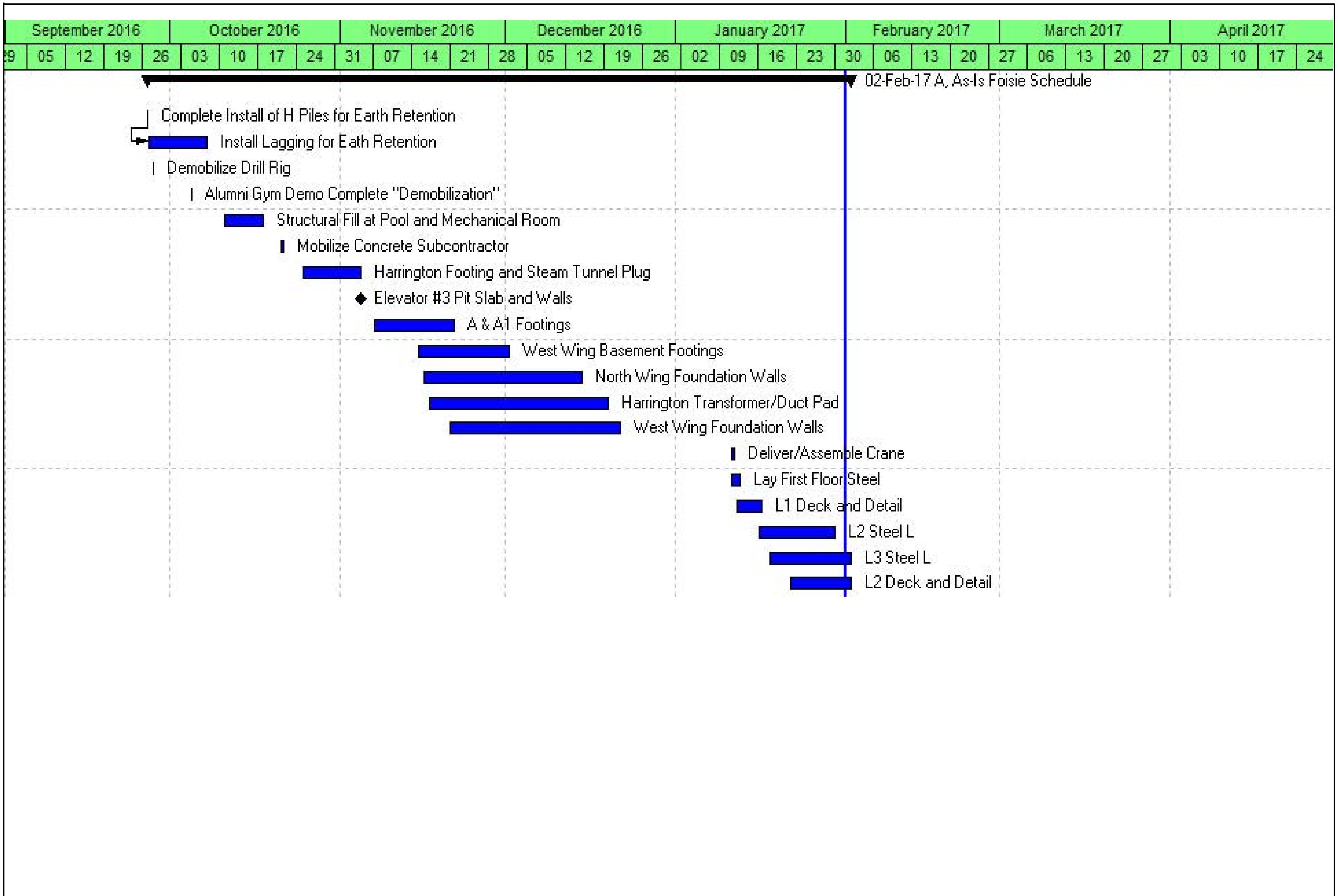
Other ____

The manner in which the handover process of information from subcontractor to CM and owner will be through the BIM technology_______________________________

If conditions require information to be handed over in paper documents check box [ ]

Appendix K Picture Tracking of Project Progress

As-Is Foisie Schedule			Classic WBS Layout			
Activity ID	**Activity Name**	**Original Duration**	**Early Start**	**Early Finish**	***Picture Link***	
As-Is Foisie Schedule		74				
A1000	Complete Install of H Piles for Earth Retention	1	09/27/2016	09/27/2016	*Click Here*	
A1010	Install Lagging for Eath Retention	9	09/27/2016	10/7/2016	*Click Here*	
A1020	Demobilize Drill Rig	1	09/28/2016	09/28/2016	*Click Here*	
A1030	Alumni Gym Demo Complete "Demobilization"	1	10/5/2016	10/5/2016	*Click Here*	
A1040	Structural Fill at Pool and Mechanical Room	5	10/11/2016	10/18/2016	*Click Here*	
A1050	Mobilize Concrete Subcontractor	1	10/21/2016	10/21/2016	*Click Here*	
A1060	Harrington Footing and Steam Tunnel Plug	9	10/25/2016	11/4/2016	*Click Here*	
A1070	Elevator #3 Pit Slab and Walls	4	11/4/2016	11/9/2016	*Click Here*	
A1080	A & A1 Footings	11	11/7/2016	11/21/2016	*Click Here*	
A1090	West Wing Basement Footings	13	11/15/2016	12/1/2016	*Click Here*	
A1100	North Wing Foundation Walls	24	11/16/2016	12/15/2016	*Click Here*	
A1110	Harrington Transformer/Duct Pad	23	11/17/2016	12/19/2016	*Click Here*	
A1120	West Wing Foundation Walls	20	11/21/2016	12/22/2016	*Click Here*	
A1130	Deliver/Assemble Crane	1	1/11/2017	1/11/2017	*Click Here*	
A1140	Lay First Floor Steel	2	1/11/2017	1/12/2017	*Click Here*	
A1150	L1 Deck and Detail	3	1/12/2017	1/16/2017	*Click Here*	
A1160	L2 Steel L	5	1/16/2017	1/30/2017	*Click Here*	
A1170	L3 Steel L	5	1/18/2017	2/2/2017	*Click Here*	
A1180	L2 Deck and Detail	5	1/22/2017	2/2/2017	*Click Here*	



Actual Work | Critical Remaining Work | Summary
Remaining Work ◆ | ◆ Milestone

TASK filter: All Activities

Complete Install of H Piles for Earth Retention

Install Lagging for Earth Retention

Start

Finish

Demobilize Drill Rig

Alumni Gym Demo Complete "Demobilization"

Structural Fill at Pool and Mechanical Room

Mobilize Concrete Subcontractor

Harrington Footing and Steam Tunnel Plug

Start

Finish

Elevator #3 Pit Slab and Walls

Start

Finish

A & A1 Footings

Start

Finish

West Wing Basement Footings

Start

Finish

North Wing Foundation Walls

Start

Finish

Harrington Transformer/Duct Pad (Start Only)

West Wing Foundation Walls

Start

Finish

Deliver/Assemble Crane

Lay First Floor Steel

Start

Finish

Level 1 Deck and Detail

Start

Finish

L2 Steel L

Start

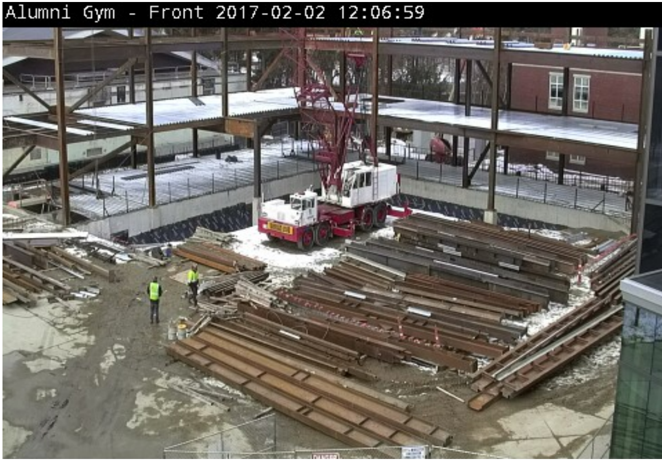
Finish

January 30th

L3 Steel L

Start

Finish



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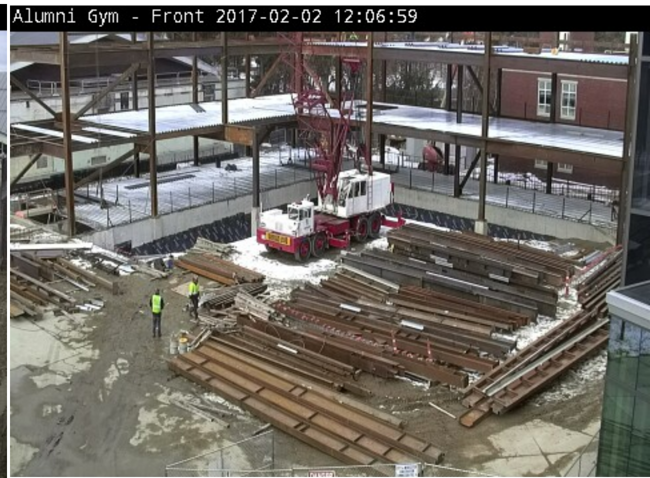

Appendix L MQP Proposal Document

Foisie Innovation Studio II

Submitted to the Faculty of the
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree of Bachelor of Science
In Civil Engineering by:

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October 13, 2016

Abstract

The Foisie Innovation Studio II MQP aimed to investigate three subjects of the construction. First, a foundation for the transferring of the BIM models and other handover documents from Shawmut Design and Construction to Worcester Polytechnic Institute was conducted. Second, an alternative proposal for the structural design of the proposed green roof was developed. The green roof is currently in a retrofit state to accommodate a green roof if WPI would like to add it in the future. Finally, a project management analysis was conducted to track the schedule, costs, and changes and issues that developed with the construction.

Authorship

Abstract

Acknowledgements

Capstone Design Statement

Professional Licensure Statement

1.0 Introduction

2.0 Background

3.0 BIM to Facilities

4.0 Project Management

5.0 Conclusions

The signatures below indicate the acceptance of the above

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Capstone Design Statement

- Economic
- Social
- Sustainability
- Constructability/manufacturability
- Health/safety

Professional Licensure Statement

- FE
- PE
- Superintendent license

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1.0 Introduction

Alumni Gym has been seen by many generations of WPI students since its construction in 1915. The building was nested between Harrington Auditorium and Higgins Labs at the northeast region of the WPI quadrangle. Since the construction of the new Sports and Recreation Center in 2011, Alumni Gym had been vacant. WPI had commissioned for a study in 2013 to be to renovate the old Alumni Gym, however the estimated cost was to be over $18 million. In the eyes of WPI and Assistant Vice President of Facilities Alfred DiMauro, “modernizing the building was impractical” because “it would create a financial hardship and an inefficient use of the building.” (Collins et. al. 2016) In October 2014, WPI Alumni launched a fundraising project to help fund the creation of the Foisie Innovation Studio. (WPI 2016) There was also a challenge grant created in January of 2015 by the George I. Alden Trust for $3 million that would only be fulfilled if the school raised $9 million in eighteen months. (WPI 2016) In total, $18 million was raised by about 1,550 donors ranging from first time donors to some that have not donated in several years. (WPI 2016)

Since the fundraising, WPI announced that Alumni Gym would be demolished and make way for the brand new Foisie Innovation Studio and Messenger Residence Hall after graduation in May of 2016. (Collins et. al.) This new landmark building that will be part of the WPI campus is a $49 million, 78,000 square foot facility that was designed by Gensler and constructed by Shawmut Design and Construction. (WPI 2016) The Messenger Residence Hall will feature space for one hundred forty students. (WPI 2016)

This MQP has three objectives associated with the construction of the Foisie Innovation Center. First delivering a BIM model and other close out documents from the general contractor to WPI, a redesign of the green roof that was initially proposed, and a project management narrative that tracks the schedule, costs, and changes for the project.

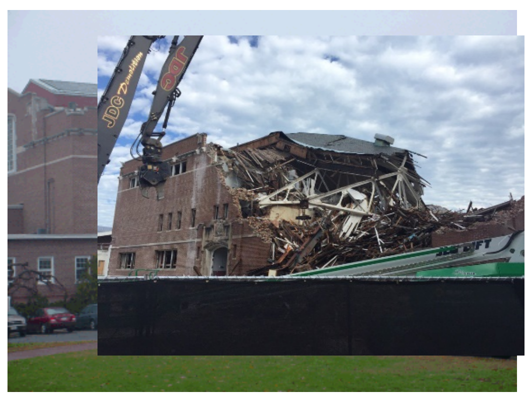
The report begins by providing a background of the various topics that will be covered. This begins with the documentation of the demolition of Alumni Gym and information on the new Foisie Innovation Center. A look into how BIM can be used along with facilities management is investigated and describes the current environment at WPI. More investigation was done on other document transfers from contractor to owner relating to CMMS (Computerized Maintenance Management Systems), and COBie (Construction Operations Building Information Exchange). Also a look into the structural integrity of the roof was investigated to either create a new green roof design if the school chooses, or redesign the structure to lower costs if no green roof is desired.

The final deliverables were an ongoing process throughout the project and at the conclusion a method for transferring information from Shawmut to WPI Facilities Management was recommended. This was done by transferring the BIM to WPI (this will become more clear as the project develops. The final designs for the green roof and option of no green roof and lessened structure were represented by a (5D? This will also change as the project progresses) model. Finally the project management aspect of costs and scheduled were documented to show how efficient the project was.

2.0 Background

This literature review provides background knowledge and details regarding the Foisie Innovation Studio and the various components of the MQP. It first reviews the stages of construction of the Foisie Innovation Studio has underwent leading up to its current state. Information regarding the building itself and the advantages of building information modeling for facilities management purposes are also evaluated in this section. The pros and cons of various computerized maintenance management systems are discussed, and the COBie model in particular is looked at in great detail. Lastly, a background on green roofs is provided.

2.1 Alumni Gym Demolition



Demolition of Alumni Gym began shortly after the graduation of the class of 2016 in May 2016. According to the preliminary master schedule for Shawmut, demolition was to be completed by September 19th, 2016. The demolition was done by JDC Demolition (60 Gerard St, Boston, MA) and by the final week of September, JDC had only one machine left cleaning up for the site work to be done next. The demolition consisted of bringing the building down in sections. Abatement had to be done on hazardous materials, like asbestos, prior to demolition of the building. (Jess Lussier) In the estimation of the costs for demolition, the estimators were conservative on the abatement amounts because there were some areas of the building that could not be seen and measured. (Jeff Lussier) There was a $21,040 abatement reconciliation because of the extra work that had to be done for areas that were blind before demolition.

The demolition started by gutting the entire Alumni gym then removing the glass windows. The building was taken down in sections because of the close proximity to other buildings like Harrington Auditorium, Higgins Labs, and the Rubin Campus Center. Once the building was leveled, JDC Demolition worked on separating the different materials from Alumni. Metal, concrete, and masonry were all divided into separate piles and trucked out to their specific dumping or recycling sites.

2.2 Foisie Innovation Studio

Plans for design and construction of the Foisie Innovation Studio took form in the past few years and WPI Alumni launched a fundraising project to help fund the effort (WPI 2016). $18 million was raised in order to fund the building that would ultimately take place of the Alumni Gym on campus. Final plans designed by Gensler call for a four story, 78,000 square foot structure that will cost Shawmut Design and Construction $49 million to deliver to WPI. The building will serve a variety of purposes on campus. The first floor will feature a robotics lab, maker space, high-tech classrooms for Great Problems Seminars – courses that introduce first-year students to team-based projects focused on real-world problems as well as a cafe (WPI 2016). The three floors above the innovation center will serve as a residential hall for first year students.

2.3 Primavera P6

Two of the most important challenges a contractor must overcome are delivering the project on time, and within budget. There are many construction software used to facilitate the tracking of these two criteria. One of the most popular tracking software used on projects all over the world is Primavera P6. This software has the capability of updating and tracking schedule activity progress from a time standpoint. Additionally, Primavera P6 is able to keep track of labor costs, equipment, and material resources (P6Pro). Shawmut design and construction is currently using P6 as a means of tracking the activities that takes place on site among all the subcontractors involved in the project. Items tracked include the dates the subs are scheduled to be onsite, the dates they actually are on site, and the duration quantified in the number of days they remain on site. Before the Foisie Innovation Center began construction, the project team laid out the duration time of every activity, and phased the project as necessary. This information was input into P6, and the software determined the project's critical path. With this tool, Primavera P6 plays a major role in minimizing schedule delays.

2.4 Building Information Modeling and Facilities Management

Building Information Modeling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. (Autodesk, 2016) The implementation of Building Information Modeling and facilities management is slowly coming to the forefront of the construction industry and gaining momentum. At the conclusion of a project, the handover process of documentation from the general contractor to the owner can be overwhelming. The owner receives electronic and paper information regarding the building's structure, MEP systems, cost information and schedules, and much more. This may take months for the owner to sort through the information to integrate it into one organized system that can be easily accessed. The current plan for WPI and Shawmut to conduct the handover process will consist of Shawmut continually updating their Revit and Navisworks models. At the completion of the project, Shawmut will handover the most complete as built models in Revit and Navisworks to WPI having subcontractors give them as much information as possible about their MEP systems and other equipment installed. (Lussier, 2016)

Currently, BIM technologies are being used to make this handover process much easier and better for the owner. For example, the U.S. General Services Administration (GSA) is requiring delivery of spatial program information from building models for major projects; the U.S. Presidential Executive Order 13327, promotes the creation of a common infrastructure to facilitate effective information sharing/reuse. (Alvarez 2014) Building information modeling is currently using computer software to create a three-dimensional (3D) model of a project where attributes and information can be stored on specific physical systems in the model. (Bertin et. al. 2011) A WPI project team created two three dimensional models that implemented BIM for facilities management for the Sports and Recreation Center. (Bertin et. al 2011) They used Autodesk Revit to create the model, then used Autodesk Design Review to display the model with the information associated with its components. Since BIM was not used collaboratively through the construction of the WPI Sports and Recreation Center, the creation of the models and supplying the necessary information is a time consuming process. U.S. General Services Administration (GSA) has initiated several pilot projects to investigate the implementation of

BIM for FM to try to get all parties of a construction project to work collaboratively with BIM throughout the entire project. (Alvarez 2014)

BIM technologies currently have limited standards for their use and handover to an owner. There are new and improving specifications that are being used to facilitate the exchange of electronic information of BIM object data. Two of these specifications are the Construction Operations Building information Exchange (COBIE) specification and the Industry Foundation Classes (IFC). (Alvarez 2014) COBie is discussed more in section 2.5, but the IFC if the most successful standard for interoperability within BIM. (Alvarez 2014) The IFC allows interoperability between different software programs and BIM because it is the open and neutral data format for openBIM. (Model Support Group) With the implementation of COBie, IFC, and other resources, BIM can be effectively and easily transferred to an owner for facilities management.

2.4.1 Revit

Revit is a building information modeling software for architects, structural engineers, MEP engineers, designers and contractors (Autodesk). Revit was the BIM tool used by Gensler in their efforts to design the Foisie Innovation Center. Revit can also be extremely useful upon completion of a construction project. Since the model has the capability to contain such a high level of coordination detail, it can be passed along to facilities management for operational and maintenance purposes. For example, if the Revit model contains the as-builts of all mechanical systems, it will include the location of every shutoff valve in the entire building. These as-built details can be exported from Revit to a viewing platform that allows for additional information to be integrated into the interface. If a situation arises that requires the attention of one of the valves, it can be located quickly and easily be the facilities management team. The rapid response from facilities management to such issues will inevitably reduce future mechanical issues pertaining to the building.

2.4.2 Navisworks

Navisworks is a program that converts large Revit 3D model files into smaller 3D models that are far more manageable for a large number of team member. Shawmut Design and Construction uses Navisworks for the Foisie Innovation Center project as a means to track the coordination of various trades on site. Navisworks essentially is a viewing interface that can receives various coordination models and combine them into one master plan which can be viewed easily. One of the primary purposes all the subcontractors coordination models are imported into Navisworks is for its ability to detect coordination clashes. Clashes most commonly occur between MEP systems involving pipes, fittings, and ducts. Other clashes occur among structural component of the building. It is most common to find clashes in confined areas. The use of the clash detection software can avoid delays, design changes, materials costs and budget overruns (BIM Handbook).

2.5 Schooldude

For most facilities management personnel, the standard method of keeping up with the life cycle of a building is through the use of a Computerized Maintenance Management System (CMMS). A CMMS is s software that is used to schedule and record operation and preventive/planned maintenance activities associated with facility equipment. (CMMS n.d.) WPI currently uses Schooldude as its CMMS software.

There are currently 6,000 schools, including WPI that use Schooldude for their CMMS. (school dude). This management system has the capability of automatically creating work requests, and the requests will be assigned to the correct work division i.e. IT, facilities, maintenance, scheduling etc… Throughout the United States, over 2,280,260 work requests were filed last year through Schooldude. The system can also be used for organizational purposes if the building is linked to the maintenance system. For example, if a particular room in the building needs to be reserved for an event, various details can adjusted in preparation. The HVAC, security, and room layout can be manipulated with the assistance of schooldude. (Schooldude)

CMMS software provides a variety of functions to their clients to ensure that buildings are maintained properly and that maintenance is usually preventative rather than reactionary. CMMS software capabilities include but are not limited to operating locations, equipment, resources, safety plans, inventory control, work requests, work order tracking, work management, quick reporting, preventative maintenance, utilities, facility and equipment history, purchasing, facilities maintenance contracts, and key performance indicator metrics. (CMMS n.d.)

WPI uses Schooldude primarily for its work order function. WPI has a list of their buildings, equipment, and tradesmen that can all be accessed when creating a work order. (Tomaszewski, 2016) Any person on the WPI campus that has access to Schooldude can file a work order to be reviewed and completed by the facilities and maintenance staff. Schooldude also has a feature for preventative maintenance, but WPI noted that they do not have the amount of personnel needed to be able to keep up with preventative maintenance. (Tomaszewski, 2016) WPI also uses Schooldude to keep track of its inventory of items and materials. WPI noted that it would like to have better use of School by implementing BIM technologies. Jim Bedard (his title) stated that he would like to see Schooldude contain all the information regarding equipment, manuals, warranties etc, and a BIM model that displays the location of the equipment, shutoffs, valves, etc.

2.6 COBie

COBie (Construction Operations Building Information Exchange) is an information exchange specification for the life-cycle capture and delivery of information needed by facility managers (National Institute of Building Sciences). It was first created by the US Army Engineer Research Development Center with collaboration and assistance from the National Aeronautics and Space Administration (NASA). Its intended purpose is to be a standardized approach that will organize all the documents that are given to the owner during the handover process upon the completion of a construction project.

COBie can be generated both automatically and manually. There are some commercial software systems that automatically create and exchange all the information included in COBie, and eventually all data within BIM applications will be able to be transferred seamlessly into FM systems.(Alvarez 2014). However, most software vendors today do not support COBie, so it has primarily been created and exchanged manually in a series of structured and related spreadsheet. (Teicholtz 2013). For the Foisie Innovation Center, COBie will be used as a general guide for determining information to be handed over to facilities management, but it will not be completely adopted for the process.

2.7 Project Management

Project management plays a large role in the construction industry. Project managers and project engineers ensure that projects run smoothly and efficiently. They are responsible for subcontractors, architects, and other parties involved in the design and building process. The main focuses of project management are cost, schedule and quality. The cost of a project must be tracked in order to make sure that the owner's budget is met and will also provide a profit to the general contractor. The schedule also needs to be maintained because in the world of construction "time is money" and delays will cause a loss of time and loss of money. Being behind schedule can cause other activities to start later than planned if they are part of the project's critical path. A project management team is responsible for the projects buyout process. They must select the lowest costing and most reputable subcontractors for all the scopes of work that are required for the completion of the project. The buyout process is critical for any project's success, because the subcontractors chosen to work on site will inevitably have bearing on the cost, schedule, and quality of the project.

2.7.1 Procore

Procore is a cloud based construction management software. It is used by many general contractors, primarily for document management purposes. Procore provides a platform for users to collaborate on projects and view various documents, including submittals, RFIs, contracts, schedules, and drawings. It also enables contractors to easily create punch list and assign responsibility to a specific individual once they have been added to the project directory. Everyone from general contractors and architects to engineers and construction management firms are able to edit and share information about the project from the jobsite. Shawmut Design and Construction uses Procore on the Foisie Innovation center project in order to maintain proper documentation of the project, and improve and simplify collaboration among team members

2.8 Green Roofs

Green roofs are an alternative to a conventional roof. It is defined as a living extension of a roof. The main components of a green roof are a waterproofing membrane with root barriers, drainage systems and filter fabric, the growing medium, and the vegetation (Tolderlund, 2010). They provide many benefits like: reducing the heat island effect, having better insulation properties, reducing noise pollution, maximizing urban land use, improving roof span, and greatly reduce storm water runoff (Rodrigues et al. 2012). There are two main types of Green roof systems “extensive” and “intensive”.

Extensive green roofs are generally have less medium and are therefore shallower. The vegetation is low growing, and more resilient.. This style requires and allows for less maintenance and are more directed towards functionality than aesthetics (Oberndorfer et al., 2007). The soil depth can be as shallow as four (4) to six (6) inches. An extensive green roof has less loading associated with it because it has less soil, and vegetation. There are a few styles The load can be between 15psf and 55psf when fully saturated (Tolderlund, 2010). This type requires little to no maintenance or irrigation. This type can cost anywhere from $10 to $30 per square foot (Oberndorfer et al., 2007). Extensive green roofs are often less expensive, allow for a larger area to be covered, and are easily replaced, and thus good for retrofit projects (Tolderlund, 2010).

Intensive green roofs are deeper and have more of an aesthetic feature to them. These weigh significantly more because they have more medium, and larger vegetation, and are often designed to handle pedestrian traffic. The load can weigh 80psf to over of 150psf and can have a significant impact on the structure (Tolderlund, 2010). The maintenance required also resembles a ground level garden and may include irrigation systems. There are no depth restrictions except for design requirements, but it is usually greater than 6 to 8 inches (Tolderlund, 2010). The cost is also more abstract because of the variances in design (Oberndorfer et al., 2007).

2.8.1 Green Roof Design

There are many different things to consider when designing a green roof. Every green roof is different because every building is different. Factors like climate, budget, building size and shape, design objectives, and accessibility all affect the size and type of green roof. The climate dictates the thickness of the soil because it needs to be able to handle the extreme temperatures and insulate the building well. The soil also needs to be able to stay in place through wind and rain. The vegetation also needs to be able to handle the extreme temperatures and varying light conditions. The purpose of the roof also needs to be evaluated; is it to help with LEED accreditation, for aesthetic purposes, or because it is cheaper in the long run. The roof also needs to be designed in a way that makes maintenance and replacement as easy as possible. To do this the access onto the roof needs to be identified, and the methods of how to replace and clean vegetation, drainage, and the many layers of the roof (Tolderlund, 2010).

The most important aspect of a green roof is the structural portion. How is the roof going to be loaded differently if a green roof is going to be included? The loads that need to be considered include the soil and vegetation weight fully saturated with water. The weight of the different components like waterproofing, erosion control, irrigation if included, and the live load during and after construction (Tolderlund, 2010).

2.8.2 Components of a Green Roof

The basic components of a green roof, extensive or intensive, in no particular order, are vegetation, growing media, filter mat, drainage layer, insulation layer, root barrier, and waterproof membrane. Depending on the cost and design goals these layers can be adjusted. For example, the insulation layer is often underneath the roof deck. The layers are all very important to the function of the roof and also to prevent damage to the building. Each layer needs to be chosen and installed by licensed professionals to ensure the quality of the product.

3.0 3D Model and Information Handover

The handover process from contractor to owner and for long been the transferring of many paper documents. These documents include information about the building in terms of area, room volume, equipment, and all the information associated with the equipment and MEP systems in the building. In the present day, construction is evolving with technology and a lot of today's handover processing are using computers and BIM models to help with the handover process. BIM is now being implemented to transfer information to a building owner's facilities management to better maintain the new building.

3.1 BIM to Facilities

As described in the background, the transferring of the BIM model to facilities management during the handover process is crucial to the life cycle of a new building. Facilities needs to have the information necessary in order to purchase new components, locate and fix issues with equipment, and be able to find shutoffs and valves in case of emergencies. BIM is a great tool for this and can be combined with other existing software to create an extensive information and visual representation of a building for facilities management. This project will use Schooldude, Autodesk Navisworks, and Microsoft Sharepoint to transfer the BIM model and information from Shawmut Design and Construction, to WPI Facilities Management.

3.2 Utilizing Schooldude

Worcester Polytechnic Institute uses the software Schooldude for all of their facilities management needs. They mainly use the work order capability of Schooldude to create work orders for issues that occur on campus. Other features that are used but not to their fullest extent are the inventory and equipment information. This project will work to better use those capabilities of Schooldude by taking the information from the Foisie Innovation STudio and BIM model and transferring that information into Schooldude. WPI has already stated that they want the full amount of information in Schooldude for the equipment listing. (Jim Bedard, 2016) The information for equipment and MEP systems will be determined based on the spreadsheet of assets defined by WPI and Shawmut. (shown in Appendix A) By including this information in Schooldude, facilities workers will be able to view the Schooldude website and access the information regarding a certain components that needs maintenance in the Foisie Innovation Studio. Using Schooldude will also be paired with other software such as Navisworks and Sharepoint in order to get all information needed.

3.3 Utilizing Navisworks

WPI facilities has stated that they want to implement the use of BIM and the model of the Foisie Innovation Studio to help with facilities management. The facilities staff does not want the software of Schooldude and the BIM model to be integrated together. They would like for the model and Schooldude to still be two separate entities. (Jim Bedard) The reason for the separation of the information is so the facilities workers do not have to be retrained on how to use BIM technologies such as Autodesk Revit. The Revit model will be placed into Navisworks where the components of the model cannot be changed. Information however, can be put into the Navisworks model which can label parts and provide information about certain items in the model. This will allow individuals to be able to use this model to pinpoint the location of equipment that needs maintenance, where a light bulb needs to be changed, or a certain valve that needs to be shut off. Then the Schooldude profile for the equipment in question can be used to acquire more information on the equipment in question and complete the open work order.

4.0 Project Management

The project management aspect of the project will investigate many parts of the Foisie Innovation Studio construction process. By attending weekly owner meetings with the Shawmut project team and WPI representatives, our team will be up to speed with the project's progression. Gaining access to Shawmut's construction management software, Procore, will also assist the team in understanding the complete scope the of Foisie project. The efficiency of the project based on time and money will be closely tracked. In addition, the buyout process, and subcontractor performance will also be analyzed on a few levels. Issues that develop from week to week, and how they are resolved the by the Shawmut team and WPI will also be documented throughout the project.

4.1 Schedule and Subcontractor Progress

The schedule and time of the project will be tracked via Primavera P6 and pictures that are taken from the WPI Foisie Cams live feed. Progress will also be tracked by comparing the baseline schedule with the actual as built data. The Primavera program will be used to input the subcontractors to schedule their progress as the project develops. Each subcontractors start and end date will be included along with their final bid price that was awarded to them through Shawmut.

4.2 Cost Tracking

Costs will be tracked by following the GMP cost sheet that Shawmut has developed. The GMP can be compared to the actual bid amounts for the items that are listed for the project. This can show loss or gain in budget on certain items as they are built. The GMP for the beginning of the project was $37,880,275 after insurances, bonds, general conditions, fees, and contingencies. Other costs such a reconciliation fees and change orders will also be documented throughout the project and their impact on the overall budget.

4.3 Monitoring Issues and Changes

Another important part of project management is the strategy behind dealing with problems and changes that come up during a project. These changes and ongoing discussions will be documented to show how the team members of the Foisie Innovation Studio worked together to a common goal. One example is the cafe that is going to be located on the first floor of Foisie. The original design was to build a kitchen for a larger food vendor to be used such as Starbucks, but the scope of the project and the size requirements changed the design to not build a kitchen and only having shelving space for the new vendor. The changes and problem solving will be documented to show why an issue arose, how it was dealt with, and why a certain outcome was reached. These factors may be because of time, budget, or even esthetics.

5.0 Green Roof Design

5.1 Steps Followed to Create New Design

The goal is to design a green roof under the impression that the green roof will not be added. The design team with Gensler has currently designed the roof to include a retrofitted green roof. The design our team will be creating will not include the option of a green roof. During the process many things need to be evaluated. The school is looking to ascertain a LEED certification, and analyze the short and long term cost impact of the green roof. There is not any regulation or design standards for a green roof, so information from the Worcester Unum building green roof is being used as a guide.

The first task is to examine at the design of the current roof structure being used by Shawmut and Gensler. The design of the roof structure needs to be evaluated for what the design loading was, and how the green roof integrates into the structure of the roof itself. The methods that were used needs to be looked at too. As well as the cost analysis, schedule, and constructability of the roof and retrofit done by Shawmut.

The second task is to figure out which materials will be used and the maintenance and construction access needed for the roof in order to figure out the loading for the roof. The Massachusetts state building code also needs to be obtained to find snow loading, and other typical loading for this type of roof. The design will also include how much self-weight of the roof needs to be included for each beam or girder. The loading will be outlined in a table or spreadsheet for easy access. Once the loading is identified the design process will need to be one according to the American Institute of Steel Construction (AISC). These two methods are the Load Resistance Factor Design (LRFD) and American Stress Design (ASD).

The design process will evaluate the design used by Shawmut compared to the new reduced loadings. The beams will then be examined to see the extent they are over designed, or if reductions in size or placements can be implemented.

Each beam and girder will be evaluated according to each unique load case based upon the predetermined design loaded. The beams will be designed with a set of hand calculations looking specifically at: design moment, deflection and deflection limits, and flange width. The next step is to compare the hand calculations to an excel sheet and then to RISA 2D to make sure the calculations were within an acceptable variance.

Once the calculations have been confirmed, a new design needs to be assessed in order to provide the most effective roof, while being cost effective. Each beam and girder size and shape needs to be reevaluated based on the new loading and see if reductions can be made.

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Appendix A

Division	Description	Possible Attributes	Site	Building	Asset Group	Asset Classification	System	Sub-System	Asset Type	Position	Floor	Zone	Room	Asset Priority	Installation Date	Cost	Manufacturer	Model #	Serial #	Asset Tag	BTU	CFM (MIN)	CFM (MAX)	HP	Cubic Feet	Gallons	Tonnage	Inches	GPM	Lbs	Speed	Pressure	Operating Load	Efficiency	Quantity	Refrigerant Type	Fuel Type	Date Acquired	Vendor Name	Vendor Warranty Expiration Date	Manufacturer Warranty Date	Voltage	Amps	Phase	Watts	Trip Setting	Motor Cat #	Heat Source	Output KW	Water/Steam	Auto/Manual	Comments	gallons per minute
14 00 00	Conveying Equipment	N/A																																																	
	Electric Traction Elevators	O&M													X	X	X	X	X	X					X						X							X	X	X	X	X											X	
21 00 00	Fire Suppression	As-built																																																	
	Valves	O&M	X	X			X	X		X	X	X	X		X	X	X	X		X								X				X			X			X	X	X	X									X	X	X	
22 00 00	Plumbing	As-built																																																	
	Piping	N/A	X	X			X	X		X	X	X	X		X																																			X	
	Pumps	O&M	X	X			X			X	X	X	X		X	X	X	X	X	X												X						X	X	X	X									X	X	X	
	Valves	O&M	X	X			X			X	X	X	X		X	X	X	X	X	X								X				X			X			X	X	X	X									X	X	X	
	Plumbing Fixtures	O&M	X	X						X	X	X	X		X	X	X	X																X	X			X	X	X	X											X	X
23 00 00	Heating, Ventilating, and Air Conditioning (HVAC)	As-built																																																	
	Piping	N/A	X	X			X	X		X	X	X	X		X	X												X				X			X			X	X	X	X											X	
	Pumps (hydronic, condensate, etc.)	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X												X		X	X			X	X	X	X									X		X	
	Dampers	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X								X							X			X	X	X	X											X	
	Valves	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X								X				X			X			X	X	X	X									X		X	
	Duct	O&M	X	X			X	X		X	X	X	X		X	X	X											X										X	X	X	X											X	
	Equipment	O&M	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X													X	X	X	X	X	X	X	X	X					X	X	X			X	
	Controls	N/A	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X															X			X	X	X	X											X	
26 00 00	Electrical	As-built																																																	
	Gear	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X																X			X	X	X	X	X				X						X	
	Switches and Circuit Breakers	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X																X			X	X	X	X	X				X						X	
	Lighting Controllers	O&M	X	X			X	X		X	X	X	X		X	X	X	X																X	X			X	X	X	X	X			X						X	X	
	Generators	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X					X									X	X			X	X	X	X								X			X	
27 00 00	Communications	N/A																																																	
	AV equipment	By owner																																																	
	IT Equipment	By owner																																																	
28 00 00	Electronic Safety and Security	As-built																																																	
	Fire alarm control unit	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X															X			X	X	X	X	X										X	
	Smoke/heat detectors	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X															X			X	X	X	X	X										X	
	Beacons/annunciators	O&M	X	X			X	X		X	X	X	X		X	X	X	X	X	X															X			X	X	X	X	X										X	