Improving Project Management Efficiency in Commercial Construction Management

A Major Qualifying Project report submitted to the faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Glossary of Terms

Project Management : Project Management : “Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.” (Project Management Institute, 2020)

Best Practices : Best practices is defined as optimizing the efficiency and outcome of the project management elements.

Construction Management : “Construction management is a professional service that provides a project’s owner(s) with effective management of the project's schedule, cost, quality, safety, scope, and function.”(CMAA, 2020).

Construction Technologies : Construction technologies are tools that are used to improve the efficiency of construction aspects.

Construction aspects : Construction aspects include tasks that are part of a construction project. (e.g. Project Scheduling, Labour force safety, Design, Budgeting, Communication, Environmental issues).

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Abstract

Commercial construction companies have implemented new technologies, such as project management software (PMS), in order to improve their construction management efficiency. However, the variety of available PM software and the inability of these software to integrate all construction aspects makes it difficult for construction companies to decide on the most appropriate software. According to this project's external survey of 80 employees working in construction companies in the Northeast region, the sample's average satisfaction on their current PM software ability to integrate all construction aspects is 6.65/10. The survey respondents also stated that quality, safety and being "on-time" are the most important factors that define a successful construction project. Based on the survey findings and on external research, this project provides a step by step thought process to help construction companies choose the most appropriate PM software. Commercial construction companies that want to improve their construction management efficiency should focus more on the functionality of the software instead of their price.

1.Introduction

Problem Statement

Construction technologies, such as construction project management software, increase the productivity of the industry's stakeholders and play an important role in the development of construction management efficiency (Miloševic & Iewwongcharoen, 2004). The amount of available options of different project management software has grown significantly due to the increased demand for project management software. Commercial construction companies often use multiple construction management software due to the inability of these technologies to integrate all construction aspects such as scheduling and safety (Louise, 2018). Their decision is based mainly on the software's functionality, ease of use and price which aligned with our Findings. However, these companies do not always choose the most appropriate software for their business needs because of the lack of correct criteria setting. In this decision making process of companies in the United States, the focus on price has increased by thirteen percent over the last 4 years as a strategy to save money in the short term (O'Loughlin, 2019). The use of inappropriate software can lead to low employee satisfaction due to the lack of construction management efficiency. To make the appropriate purchase, it is recommended for construction companies to improve their understanding of their business needs by performing internal activities such as internal surveys and further external research such as industry analysis.

2.0 Methodology

This project examines the evolution of construction project management practices over the recent years and its goal is to show the impact of project management software in commercial construction companies. The development of this project required the use of several research methods that aimed to produce valuable data that fit our needs. This section will describe the process of scoping, creating and identifying the findings that are related to our project.

2.1 Performing the External Research

After deciding on the subject of our project, our first step was to broadly research the construction industry in order to get a better understanding of it. Our research was performed through academic journals, government websites and professional societies such as the American Society of Civil Engineers (ASCE). These were found mostly through the use of the Google Scholar search engine.

Our group decided that our research on the literature review should be enriched and become more scoped in terms of the industry, the aim of the project and the time of the published journals. Thus, the team scheduled a meeting with WPI librarian (Gordon C. Library) Laura Robinson in order to improve our researching skills and methods. Our research was expanded through engines such as IBIS World and Business Source Elite which we had access through the WPI library. IBIS world guided us on the North American Industry Classification System (NAICS) and Standard Industrial Classification (SIC) which helped us define the industry that we have focused on. These two classification systems contributed to our research by filtering our

search engines with the respective industry and thus providing more scoped out results. Even though our initial industry research focused on residential construction practices we understood that this section was subject to change during the development of our project.

2.3 Creating The WPI Alumni Survey

Even though online research was essential for the development of the literature review, the group decided that sending out a survey would give us more insight on the research topic. The next step was to schedule a meeting with WPI's *Executive Director of the Office of Lifetime Engagement for Alumni Parents and Friends*, Peter Thomas. A confidentiality agreement was signed by the group members concerning the data. The main meeting subject was the sample that would receive the survey questionnaire. Our request involved obtaining contact information from WPI alumni that work in the following construction companies: Shawmut Design & Construction, Turner Construction, Suffolk Construction Company, Consigli Construction, Gilbane Building Company, Bond Brothers, Callahan Construction, Whiting Turner, Crenshaw Construction. These companies are frequent destinations for WPI alumni. In return, Peter Thomas requested to review the survey instrument before it was sent.

The sample size of the survey was 80 WPI alumni. The software used, Qualtrics, was accessible through our WPI student accounts. The instrument of the survey contained 10 questions **(Appendix B: Survey Instrument)** and the expected survey time was expected to be approximately 2 minutes. The purpose of the questions in the survey instrument is to improve our understanding on how technology is being implemented into employees working in the construction industry and help us decide which construction aspects have the most room for

technological innovation. This survey enriched our knowledge on the trends and culture that some construction companies are trying to impose on this modern era.

According to WPI regulations, surveys need to pass an approval process which is done by submitting an IRB form **(Appendix A: IRB Form).** Thus, our group scheduled a meeting with Ruth Anne McKeogh, Director of Human Subjects Research and Academic Programs in order to start the survey approval process. As requested, we made the survey anonymous by removing the first question of the survey "Write down your name". Furthermore, a survey email **(Appendix C: Survey Email)** was developed that clearly stated its anonymity, the project's aim and information about our group. The survey email was included in the IRB approval process.

After having our survey approved by the group's MQP advisor Professor Sharon A. Wulf, Peter Thomas and Ruth Anne McKeogh we sent out the survey to our sample of 80 WPI alumni. The survey was sent out a total of 3 times with the expectation of receiving a 35-40% response rate. This percentage is relatively high compared to an average external survey response rate of 10%. In this case, a relatively high percentage rate was expected due to the strong connection between WPI alumni and students. The survey was answered 41 times which translates to a 51% response rate.

2.3 Identifying The Survey Findings

For the betterment of the results' understanding, the team met with Professor Sarkis, from the WPI Foisie Business School. His suggestions were to select the most important survey questions and code the qualitative data in order to be in the position to visually present it.

Our team narrowed down the 5 questions that would be used for the analysis of this project. The first 3 short-answer questions aimed to introduce each respondent to the survey topic and are not included in this project's analysis. According to the results of question 4 "Choose the type(s) of projects you have the most experience working on?", the majority of the survey respondents work in commercial projects. This question led to the shift of our focus from the "Residential Construction Industry" to the "Commercial Building Construction" with NAICS code 236220 shown in section **3.2.0.** Furthermore, our group decided that it is essential to show the most frequent software used from the companies of the survey respondents and relate them to the employee's satisfaction of these software. Thus, the results from Question 5 and Question 6 are presented in table (5.1.2) and bar graph (5.1.3) respectively . Lastly, the results from Questions 7, 8 and 10 are graphed and described into separate graphs in the findings section. The responses of Question 9 could not be accurately interpreted and will be further discussed in **Limitations 6.0.**

2.4 Concluding On The Project's Recommendations

After reviewing the responses of the survey, our group had to decide on the direction of our recommendations. The total average satisfaction of the employees on the current project management software that they use was 6.65/10. The responses showed that the employees used multiple PM software while the group was overwhelmed with the amount of different software available online. After questioning the decision making process of commercial construction companies on PM software purchases, our research showed that in 2019 companies were more concerned about the price of the software than what they were in 2015 (O'Loughlin, 2019).

Derived from this project's external research and the WPI survey our group decided to provide a step by step thought process that commercial construction. We believe that looking at the most valued factors that define the success of construction projects are also the factors that commercial construction companies should base their decision on. The responses on question 10 are the roots of our **Recommendations 5.0.**

3.0 Literature Review

3.1 Project Management

Every project is unique and temporary with defined scope, resources and interval of time. It requires the completion of a specific set of operations in order to reach the overall goal. These operations have to be efficiently managed in order to be completed on-time and within the assigned budget. The management of these operations is what one would call project management. In other words, “Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements” (Project Management Institute, n.d.).

Over the years, based on advancements in technology and development in the industry, project manager job description has shifted. The change and evolution of projects and how they play a role in changing the society are key in the changes to the job description. This job was first utilized on projects like The Grand Canal of China or St. Petersburg in Russia. These projects are very different compared to some more recent projects such as the building of the Pennsylvania Turnpike or joining the continent of North America by a railroad (Cleland, 2004). As technology progresses, expectations for projects become more advanced and intense. In order to keep projects on time and of quality, the adaptation of appropriate project management software can make the project manager's goals more accessible.

3.1.1 Best Practices of Project Management

Usually, there are many methods and techniques to tackle a project. Choosing the most appropriate practice for a project is using best practices. Best practices can be defined as

optimizing the efficiency and outcome of the project management elements (Project Management Institute, n.d.). Even though project management aspects can be easily defined, it does not mean that the execution of them is simple. It requires great communication skills, effective scheduling and efficient use of resources.

To adequately apply the best practices, it is beneficial to utilize advancing technologies. Project managers use PM software to improve the efficiency of all the tasks such as scheduling and communication that are essential for the successful completion of the project.

3.1.2 Construction Project Management

The construction industry is arguably the largest ($974.7 billion in 2019) project-based industry (U.S. Census Bureau, 2020). Construction projects are inherently unique, tend to be awarded at short notice, are reliant on a transient workforce and exist within a complex multidisciplinary team-oriented environment. Disparate groups of individuals from different organizations are brought together for short periods of time to work collaboratively towards project goals. The unpredictability that this creates, relative to static production industries, places extreme demands on managers to respond flexibly to rapidly changing project circumstances. Project management is therefore one of the most demanding roles within the modern construction industry.

Construction project management encapsulates the following six aspects of project management itself: effective strategic and technical definition of what the project is about; the management of that definition as the project unfolds; active management of the interplay between the project's definition and the environments in which it finds itself; the timing of the project, both in its total duration and in its phasing; creating the right organizational attitudes among all the parties involved in the project's success; and, actively developing and implementing the project as it evolves (Grunberg & Noble, 2019).

A project manager (PM) is generally taken to be the person accountable for delivering a project safely, on time, within budget and to the desired performance or quality standards determined by the client. The optimum project balance occurs when the time, cost, and quality parameters are equal. A PM not only manages, but also leads the team: leading by example, gaining the trust and respect from their team through motivating, coordinating and maintaining morale. In a project context, each project is normally seen as unique and therefore the project manager must recognize what skills are required and apply them accordingly, to suit their current project role requirements. A PM uses the knowledge obtained through training, combined with skills enhanced through time and experience so they can be ready for anything that is thrown at them on the job. The vital functions of a project manager (perhaps in a rather traditional view) are: forecasting, planning, organizing, controlling, motivating, coordinating and communicating. These seven functions of a PM are extremely important in managing a job (Grunberg & Noble, 2019).

3.2.0 Commercial Building Construction Industry

The “Commercial Building Construction” industry (NAICS code: 236220) includes companies who serve as project managers or general contractors for office, retail, hotel, agricultural, education, hospitals and entertainment buildings. The members of this industry complete several construction management activities such as: planning, supervising, budgeting, estimating, scheduling, designing, engineering and contracting. Members of this industry may also oversee community relations, safety programs, labor, cost control and coordination with the owner and other construction specialists. These companies perform their work based on a variety of contracts including: design, bid, build; design-build; construction manager at-risk; and more. Revenue has grown for this industry significantly over the past 5 years and this is due to several external factors that have a major impact on industry success.

The growth and success of members in this industry relies upon several factors. The strongest factor of demand in this industry is the value of private nonresidential construction. As the value of private nonresidential construction increases, so does the demand for contractors who specialize in construction projects such as offices, warehouses, and hotels. Consumer spending also greatly affects the demand for commercial construction. As consumer spending increases, demand for goods and services rises, which incites businesses to increase supply and expand. This in turn leads to an increase in retail buildings, warehouses, and office spaces. An additional external factor that impacts the success of commercial construction is corporate profit. Corporate profit affects this industry because companies are only willing to spend money if they are making money. If profit amongst corporations is rising, businesses will be willing to hire more employees and spend more on office spaces and new locations. This ultimately affects the commercial construction industry. Another external factor that relates to corporate profit is office vacancy rates. If office vacancy rates are low (low is considered less than 10%), there may be a high demand for office spaces. This brings a great opportunity for the commercial construction businesses to find work building offices. The final external factor that will be discussed is the yield on a 10-year Treasury note. This rate affects commercial construction because if the rate is low then it is much more affordable to finance a construction project. If low rates make construction more affordable, then businesses will be more willing to invest in construction projects which will benefit the overall industry (Madigan, 2019).

Over the past 5 years leading up to 2019, this industry has experienced a steady growth at an annual rate of 8.0% leading to a revenue of $234.6B. This is in response to the construction industry as a whole beginning its recovery in 2014. The growth of this industry heavily correlates

with the growth of the external factors previously discussed. In 2014, the value of private nonresidential construction increased by 11% which aided a 16.4% growth in the commercial construction industry revenue for that year. Also, over the past five years, per capita disposable income has increased at a rate of 2.4% annually. This growth enabled a 2.9% annual increase in consumer spending, one of the important external factors for this industry. Throughout this same five-year period, corporate profit remained high which allowed businesses to enlarge the workforce, ultimately decreasing unemployment. This causes businesses to invest in commercial construction by building new locations and office spaces. Since 2014, the success of the external factors that have been discussed led to the growth in revenue within the commercial construction industry (Madigan, 2019).

Although industry revenue has annually increased from 2014-2019, it is expected to decelerate over the next five years (2019-2024). Such as the industry revenue greatly accelerated due to the increase in the external factors, the anticipated deceleration is due to the projected decline of these same factors. Over these next five years, corporate spending, office vacancy rates, and consumer spending will most likely slow down. This decline will lead to the deceleration of the commercial construction industry. There will not be as high of a demand for players in this industry, so companies must do what is necessary to separate themselves from the competition to continue their success. This industry has a low level of market share concentration with the top 4 companies combining for less than 10% of industry revenue (Turner Construction is the market leader with 3%). This low level of market share concentration raises the competitiveness of this industry because there are not one or two companies that are dominating the industry. Industry players must find ways to emerge as the better option in comparison to other companies when

trying to win bids for construction projects. According to IBIS World, the most important success factor for businesses in this industry is having "access to highly skilled workforce." The workforce includes the laborers in the field as well as the members of the project management team in the office. In the upcoming years, being "highly skilled" may include being familiar and adept in the new technologies used in the industry. One method that these companies can use to separate themselves from the competition is to utilize the latest and best technologies and project management software to become more efficient, safer, and more successful (Madigan, 2019).

3.3.0 Software Development

The advancement of software technology that can be applied to construction is significant. Construction companies use such software to establish formal metrics, improve communication and tracking, provide real-time deficiency management and enhance equipment usage information. Also, construction applications have been developed that are responsible for the resolution of conflicts among participant parties in the construction development.

3.3.1 Construction [Project] Management Software (PMS)

Construction Management Software are primarily used for the establishment of formal metrics from the general contractors of the construction development. These metrics can be used as key performance indicators (KPI's) responsible for the evaluation of the construction progress. Such metrics include the scope and quality of work, safety regulations and information, the scheduling timeline and various goals that need to be reached in a specified time.

Financial goals can be included by stating ways to improve cost management. The cost is closely monitored during the whole construction process, because possible deviations from the planned budget would lead to changes in the scope and timing of the project.

There are multiple PMS available in the market and Silicon Valley entrepreneurs have switched their focus on the emerging market of such software. Companies have to identify which software is most applicable for their situation based on some fundamental questions. These questions are mostly related to accessibility, cost, transparency, reputation among subcontractors, cloud security and its ability to integrate with other products (Ogunde et al., 2018).

It is essential for PMS to include some fundamental features. Stakeholders, including subcontractors and the owner of the construction development, should have the ability to check on important updates such as the project completion time. The ability to provide real time updates about the construction in the PMS allows stakeholders to stay in touch with the progress. User-friendly reporting tools are fundamental for the improvement of communication among the general contractor and the subcontractors. Effective communication among project participants will increase their productivity and avoid potential errors (Ogunde et al., 2018).

Also, accessibility from various devices and different locations is an essential tool in order to increase the mobility of involved parties. For example, project managers on-site should be able to access the software and instantly update potential errors. All information has to be stored and preserved in a secure place. Thus, the software must contain secure cloud capabilities where important files such as the budget and construction drawings can be stored (Ogunde et al., 2018).

3.3.2 PMS in the Commercial Construction Industry

As technology and project management software continue to progress and improve, the commercial construction industry has become more reliant on the software to help their efficiency. Construction companies that work in the commercial construction industry also often complete projects in other industries such as residential and civil projects. However, these companies tend to use the same software for all the different types of projects they complete.

The software that is used in this industry does differentiate from company to company. Especially now that PMS have become more advanced and popular, there are many different options for companies to choose from. Most companies use several different software because they cannot find one that they believe is suitable for their needs or cannot integrate all the different aspects of construction such as budgeting, scheduling, estimating, and more. These technologies have become vital to the companies of this industry to communicate, organize, and adjust effectively. One of the most common PMS for the industry players is ProCore.

ProCore is a project management software specifically for construction projects that was developed in 2003 and has been used by over 1.3 million people in 125+ countries, making it one of the most commonly used PMS (ProCore, 2020). ProCore encapsulates many of the different aspects of construction and has continued to update their features to improve client satisfaction. Some features of ProCore include drawing/document management, incident management, quality control, progress tracking, and budgeting management. All the information is stored in the cloud so that the project management team, subcontractors, the engineers/architects, and the company management can all see and share information instantly. However, there are some complaints and cons to ProCore. One complaint is that it is not sufficient as a sole resource for accounting in a project. Also, some complaints have arised about the lack of ability to mark-up and edit the drawings and documents. Finally, it is expensive in comparison to most software and smaller construction companies may not be able to afford it. It costs $375 USD a month for just project management and $549 USD a month for both project management and financial management. These prices are for businesses conducting $3 million or less in construction annually. Although this may be financially and logistically reasonable for some companies, it is

not realistic or beneficial for many others. ProCore has emerged as one of the most popular and effective PMS in the commercial construction management industry, but it still does not satisfy every need that a construction project needs and it is not an option for all companies.

3.4.0 Important aspects of Construction and their Technologies

3.4.1 Safety

Construction operations can be hazardous and have high safety risks to both field personnel and to the public. According to the Bureau of Labor Statistics, the construction industry experiences fatal injuries at disproportionate rates compared to other major U.S. industries (Jones, 2016). Although construction workers account for only 5% of the overall national workforce, approximately 20% of total workplace fatalities in the U.S. occur in the construction industry. In 2016 alone, more than 900 fatalities were reported in the construction industry, yielding an injury rate of about 10%, which is significantly higher than the national injury rate of all other U.S. industries. Some have identified the limited adoption of technology in the construction industry as a potential reason behind the poor safety performance in construction.

Virtual reality in the construction industry is often employed to enhance work quality, reduce construction costs and avoid schedule delays, as opposed to improving workplace safety conditions. The use of virtual reality in a safety context is currently not a standard practice in construction, although it has recently received increased attention.

Another technology that has been used more in construction safety is augmented reality. This technology can superimpose spatially contextual information on the job site during construction operations, which can have many safety benefits. For example, smart helmets that use augmented reality can give workers real-time data about workplace conditions, such as temperature

differentials and unsafe conditions, and can send location details to managers and safety supervisors in the field office.

Other technologies that can be used to generate safety benefits include 3-D/4-D computer-aided design, building information modeling (BIM), laser scanning, radio frequency identification, robotics and automation, unmanned aerial vehicles (UAVs), wearable sensing devices, sensors, and warning systems. These technologies can be incorporated into the project during either facility design to mitigate potential construction hazards and promote workplace safety, or construction to enhance factors such as communication and collaboration between workers, supervisors and project teams.

In many cases, more than one technology can be used, either jointly or subsequently, to generate safety benefits on the job site. For example, laser scanners or UAVs are often used to scan a site and capture a detailed set of data before creating a point cloud for the deployment of a BIM model. Table 1 summarizes potential safety benefits of several technologies. The adoption of technology can bring many benefits to the construction industry. High levels of technology adoption can help the construction industry progress toward a more productive, efficient process that yields superior performance outcomes with respect to work quality, construction cost, completion schedules and safety (Jones, 2016).

3.4.2 Environmental

Environmental issues are constantly emerging alongside technological advancements. The construction industry is a big player in creating environmental issues considering the amount of energy that goes into constructing a building. The World Business Council for Sustainable Development (WBCSD) found that in 2007, 40% of the total energy usage was strictly from buildings (WBCSD, 2007). Is it becoming more obvious that the construction industry needs to

adopt and utilize green innovations and Green Building Technologies (GBTs) to decrease the negative impact it currently has on the environment.

Specific buildings that take advantage of basic resources like water, energy, land and materials are considered Green Buildings (GB.) These buildings are becoming more appropriate and help the environment by discharging less CO_2 than normal buildings. These GBs are created using Green Building Technologies (GBT's.) Some well-known GBTs are solar panels and wind turbines, but there are more recent GBTs specific to the construction industry. Technologies such as highly efficient windows, highly efficient HVAC systems, solar shading devices, and solar water heaters are becoming more relevant in modern commercial construction (WBCSD, 2007).

In the "Energy Buildings" journal it is mentioned that "cost, implementation time, and the shortage of knowledge and awareness of Green Building (GB)" are the main factors crippling the usages of green innovations. Cost is one of the bigger components that holds construction companies back. When a company is not able to afford new technologies or implement GB innovations, it is inclined to avoid change. A project manager is generally in charge of creating a budget based on the given project and providing an overall price based on the needs for the construction. If it is not a requirement to utilize these new GBT's, companies opt to avoid using them. (U.S. Green Building Council, 2003)

Another pressing factor that hinders the adoption of GBTs is the unwillingness to stray from universal or "normal" ways. "Due to its size, fragmentation, diversity, and low investments in research and demonstration, the construction industry is characterized by relatively slow rates of innovation." (WBCSD, 2007). Stakeholders involved in projects usually prefer the company to stick to a traditional construction plan.

Green buildings and Green building Technologies are important tools in limiting the negative effects of buildings on the environment. The lack of acceptance of these new technologies and

buildings will set the industry behind. Implementation of these new technologies will in turn create new jobs.

3.4.3 Scheduling

The scheduling of a construction process is a plan designated to manage materials, labor and equipment. It allows for adjustments to accommodate change orders and unexpected events**.** Effective construction scheduling is mandatory for the delivery of a project on time and within the assigned budget. The most common practices of construction scheduling are the Gantt Chart (Bar Chart) and the Critical Path Method (CPM).

The Gantt Chart was developed by Henry Laurence Gantt during 1910-1915. It was first used as a visual tool both for the scheduling and the tracking of progress in projects. Given that it is a popular project management tool today, it shows the global significance of such an invention in the 1920s. The Gantt chart quickly appeared in large construction projects such as the Hoover Dam in 1931(Gantt Chart History | Project Scheduling). Today, Gantt charts are made digitally and are often color-coded based on the type of the task or the person assigned. The digital transformation has made modern Gantt charts more visually appealing and easier to modify during the project. The chart must include the task title, start date, end date and duration of each task, as shown in **Figure 3.4.3.1 "Gantt Chart Example"**

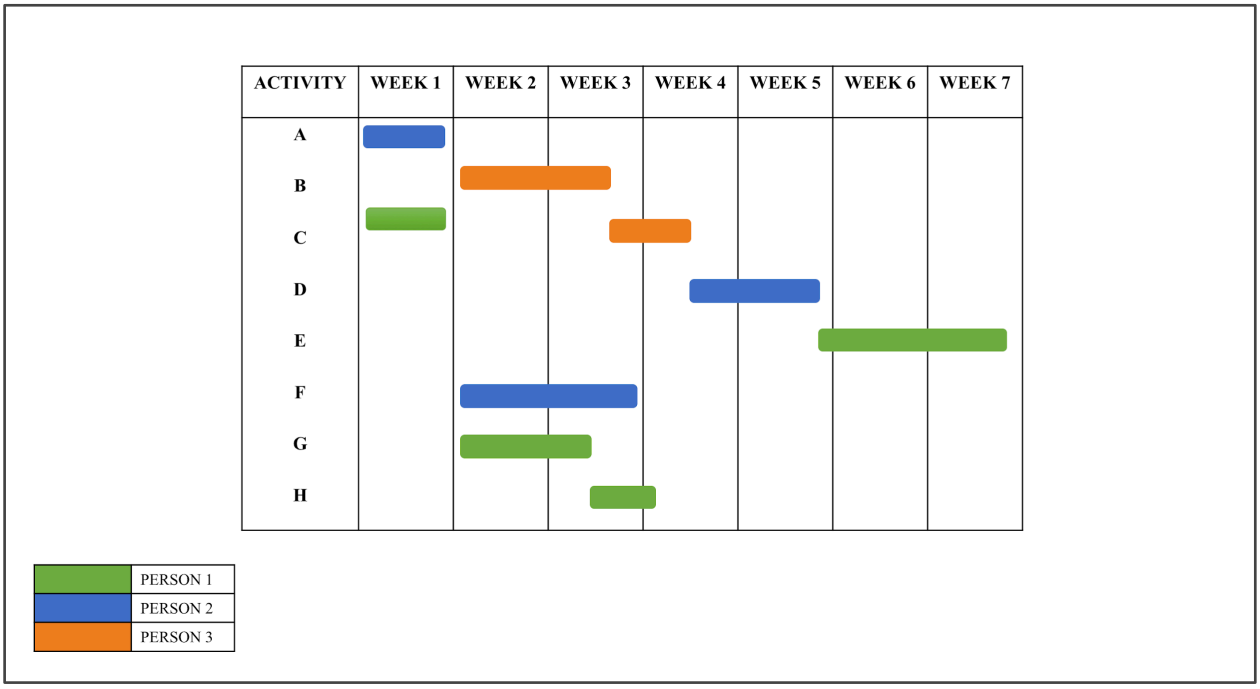

Figure 3.4.3.1 Gantt Chart Example

An alternative project planning tool is the CPM, which was developed in the late 1950's. The CPM is a step-by-step network project management tool that is very popular in the construction industry. Even though the CPM graph enriches the visual depiction of the schedule, it is not considered mandatory. Its goal is to distinguish between critical and non-critical tasks in a project and connect them in a logical sequence in order to avoid scheduling delays. The method requires the identification of the duration of each task, the immediate prerequisite of each task and the labelling of each task with a symbol. This data should be put on a table shown next to the graph. A popular way to depict tasks in a CPM diagram is with boxes that include the duration, the symbol, the Earliest Start time (ES), the Earliest Finish time (EF), the Latest Start time (LS) and the Latest Finish time (LF). Tasks that are sequential are connected with arrows. The critical path is defined as the minimum amount of time needed to complete the project. **Figure 3.4.3.2 "CPM Diagram Example"** below illustrates the CPM plan for the same hypothetical project as **Figure 3.4.3.1. "Gantt Chart Example"**

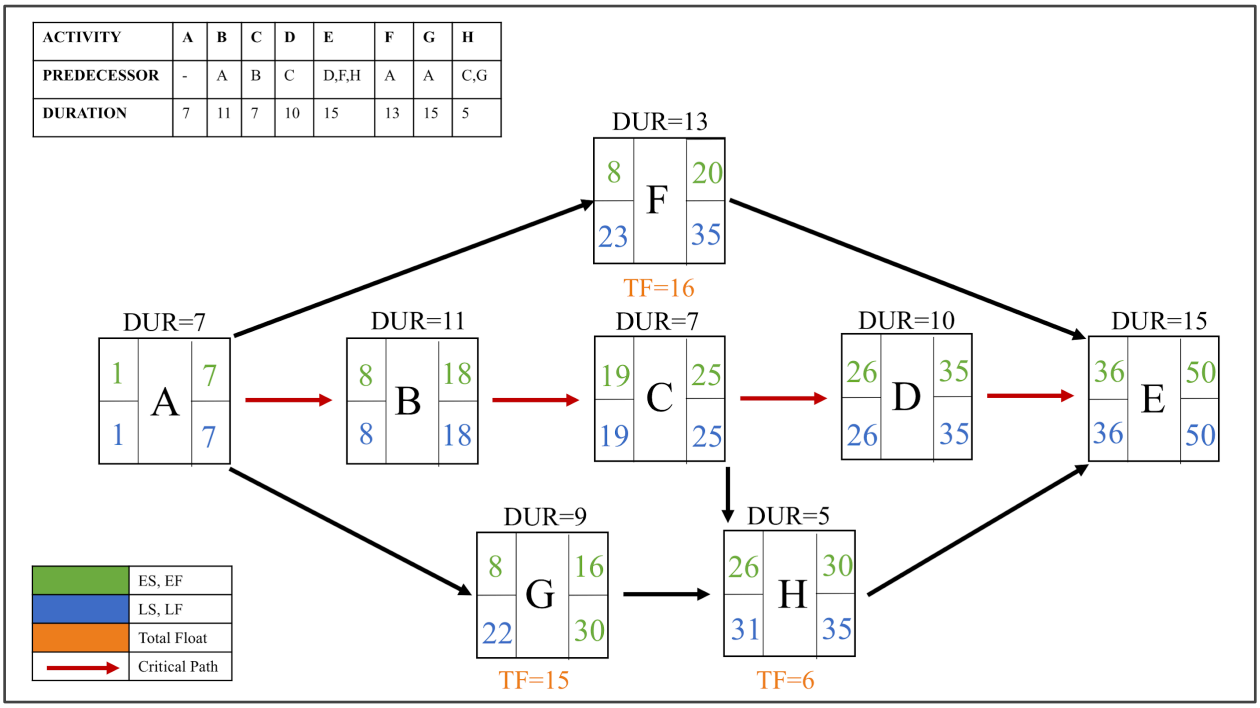

Figure 3.4.3.2 CPM Diagram Example

In the figure above, activity sequence A-B-C-D-E is identified as the longest path and therefore, the critical path. Activities on the critical path must begin immediately after their predecessor has finished, with zero margin for delays. Activities F,G,H lie on the non-critical path and are thus associated with float time. Total float time is defined as the total time (in days) that the start date of an activity can be delayed without causing negative downstream effects on the total project duration. For example, activity G can begin 15 days after its predecessor, activity A has finished without causing any delays. Furthermore, the green numbers on the left and right of each symbol in **figure 3.4.3.2 "CPM Diagram Example"** denote the ES and EF respectively, while the blue numbers expose the LS and LF of the activity respectively. Therefore, the CPM diagram

explicitly shows not only the total duration of both individual activities and projects, but also the linkage between all activities.

The main difference between these techniques is that the Gantt Chart fails to show linkage between the activities while the CPM exposes all logical connections. As CPM exposes the most efficient sequential order of activities, it can also be used to ensure optimum time-cost relationship of the activities.

According to a study by Galloway, over 96% of the contractors surveyed believed that there is an economic benefit associated with using CPM (Galloway, 2006).

In conclusion, Gantt chart should be applied to simple, linear projects where there is no need or budget for more complicated analysis.

A revised version of the CPM is the Program Evaluation and Review Technique (PERT). The main difference between the two network planning methods is that in CPM, the duration of activity is estimated with accuracy as a time-cost relationship (deterministic approach), whereas in PERT, there is room for indefinite duration of activities and therefore time is not related to cost (probabilistic approach) (Galloway, 2006).

3.5.0 Early Warning Signs in Construction Projects

Throughout the duration of a construction project, there will always be different challenges, delays, or unexpected events that occur. These situations can cause the project to go over budget or past the deadline. When evaluating a project after it is completed, it can be easy to analyze these different issues and identify the warning signs that could have led to these problems. However, it would be much more beneficial if one could identify these early warning signs (EWS) while they occur so that he or she could act on them and stop these detrimental events

from happening. It can be extremely difficult to recognize and act on EWS before they impact the project. These "crises occur for a reason, and the reasons are often ignored, covered up, or not recognized." (Williams, et al., 2010).

The complexity of the project can play a major role in the amount of possible warning signs and the difficulty of identifying them. If the construction project management team can become more aware of this issue and can improve in recognizing and reacting to EWS, then the risk of projects going over the budget or over the deadline will drop.

There can be EWS in several different aspects of the construction project. These signs can be identified in: the schedule, the relationships amongst the team or with subcontractors, the equipment that is being used, the external factors such as weather or the environment, and more. Some examples of EWS within the relationships of a project are poor communication with subcontractors, an unclear direction of the project from management, and confusion between business management and project management (Kiisel, 2011). All three of these can be identified with inefficient communication. If project managers can recognize that there is poor communication as soon as signs of this issue arise, then it can be resolved immediately instead of being ignored. An EWS with scheduling is that the scheduling team does not account for certain risks or is overly optimistic in order to please management or the customer. "Overoptimistic assessments of benefits and underestimates of problems and risks can subvert this process as a way of flagging risk that may result in an unsustainable project." (Williams, et al., 2010). If the scheduling or management team realizes that this is occurring, they must discuss it and make the appropriate adjustments necessary to the planned schedule. It is better to be realistic and account for foreseeable risks in the schedule than to be overzealous and disappoint the customer because

of missed deadlines or due to poor quality. In terms of the equipment and technology being used, it was found that "immature technology, lack of corporate technology roadmaps, and inexperienced workforce" are three EWS that occur frequently (Williams, et al., 2010). In relating this to commercial construction projects, if construction companies are not willing to invest in or are not adept in using the new technologies, then this could be an EWS that their projects could fail. These are just a few examples of several EWS that may be ignored or failed to be recognized and could potentially have a major impact on the outcome of a project.

Improving the ability of the project management team to detect EWS before issues arise or even before the project begins could be essential to the success of a project and a business. Once they are able to find these signs, they should put an action plan in order to negate the risk of a delay or issue in the project. Investing in new technology could be a major aid in identifying EWS and solving them. Owning the most efficient Project Management Software can help ensure that documents are not lost, drawings are easily accessible, and communication is effective. Also, acquiring the latest and best software and equipment can help increase the efficiency and safety of the project. Finally, technology such as virtual reality can help schedule planners visualize and plan for future risks or problems that certain tasks may have. If EWS are not recognized, then several issues can arise that can cause a project to fail, but awareness of this topic and the integration of new technologies can assist the project management team in resolving these EWS to ensure the success of the project.

4.0 Findings

This section analyzes the responses that were collected from the survey that was sent out to 80 employees in construction companies. The survey was answered by 41 employees. Overall, the results of the survey show that the majority of the employees that participated believe that construction project management software is improving the efficiency of their jobs. However, it is evident that project management software is not equally helpful in all construction aspects and processes.

4.1 Survey Demographics

The survey was sent to employees working in 8 different commercial construction companies shown in **Appendix : List of Construction Companies.** Most of the employees that responded to the survey work in the Northeast region of the United States of America. The most frequent location of these employees, in terms of states, is Massachusetts (MA). Other respondents are located in New Hampshire (NH), Rhode Island (RI), Connecticut (CT) and Virginia (VA) and Maryland (MD) and New York (NY). The common characteristic of the survey sample is WPI education. The limitations of the survey demographics will be discussed in **Limitations 6.1.**

4.2 Employee Satisfaction

According to question 6 of the survey, the respondents are generally satisfied with the project management software that is being used in their companies. This rating question had the respondents rank their satisfaction on the software that they are using with a maximum value of

10 based on the software's ability to integrate all construction aspects. As shown in **Table 4.2.1** below, the total average satisfaction of the respondents was 6.65/10.

Total Average Satisfaction (0-10)	**Range (Max - Min)**	**Mode**
6.65	6 (10 - 4)	7

Table 4.2.1 Employees' Satisfaction On Their Project Management Software

This value being over 5 implies that employees understand the value of project management software in their job. However, the fact that the value of the average satisfaction is closer to 5 than to 10, it implies that there is room for improvement.

The most frequent answer (mode) was 7, the highest answer was 10 and the least satisfied respondent chose the value 4.

4.3 Frequently Used Project Management Software

With question 5, "Do you use Project Management Software in your company? If Yes, please state the name of the software.", our group wanted to get insight on the most frequent software used. **Figure 4.3.1** demonstrates the 4 most frequent software that appeared in the responses of the survey as a percentage of the total responses.

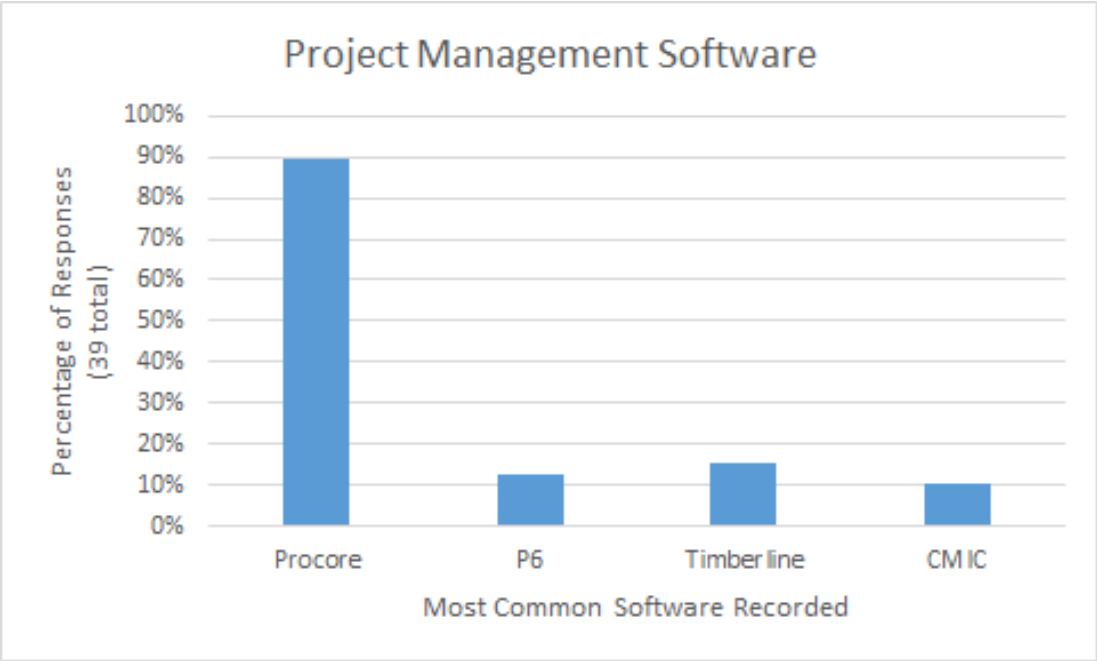

Figure 4.3.1 The 4 Most Frequent PM Software Used

Some respondents listed more than one software that are currently using. The most frequent software used, with a big difference from the second, is Procore. More specifically, 35 out of 39 employees (89.7%) that responded to this question on the survey, are currently using Procore. The other three most frequent software that appeared on the survey responses are Timberline, P6 and CMIC respectively. Other popular software that were less frequently seen in the responses are “Primavera” and “Gantt Pro” which serve for scheduling planning and “Sage” which is for file documentation.

In order to find a correlation between the software being used and the employee satisfaction, the data collected from Question 5 and 6 is shown in **Table 4.3.2.**

Software Name	Average Satisfaction (0-10)	Range (Max - Min)	Frequency
Procore	7	5 (9 - 4)	35
P6	7	5 (9 - 4)	5
Timberline	7.5	1 (8 - 7)	6
CMIC	6.5	3 (8 - 5)	4

Table 4.3.2 Employee Satisfaction On Most Frequent Software

The highest ranked software, in terms of employee satisfaction was Timberline. Timberline's lowest satisfaction value was 7 and its highest 8. The two most frequent software received an average of 7 while CMIC resulted in 6.5. The responses in Procore and P6 varied substantially ranging from values of 9 (high) to values of 4 (low).

4.4 Construction Aspects and Project Management Software

Moving on from the overall satisfaction of project management software, the purpose of Question 7 was to relate construction aspects to the software that each survey respondent is using. Thus, **Figure 4.4.1** represents the construction aspects that the aforementioned software fail to improve.

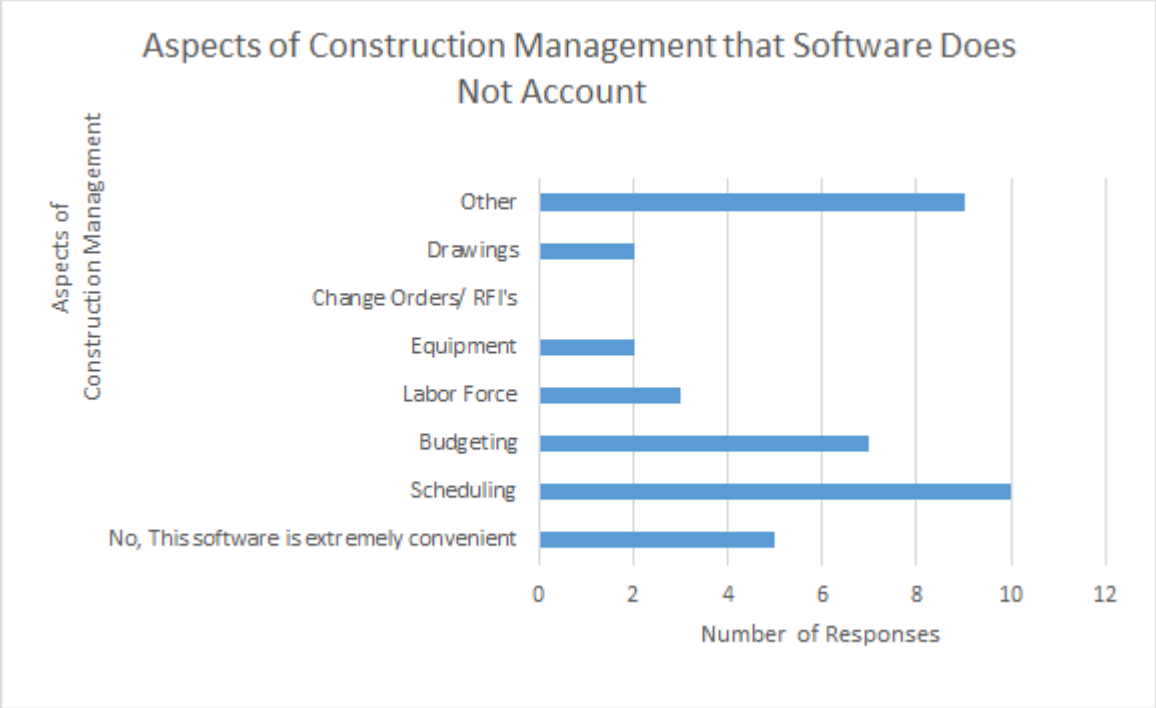

Figure 4.4.1 Aspects of Construction That Project Management Software Used Does Account

Even though scheduling techniques have significantly been improved and modernized, as described in **section 3.4.3,** it seems that scheduling software is not yet as beneficial as these survey respondents want it to be. The bar graph above shows that “Scheduling” and “Budgeting” are the two construction aspects that do not benefit the most from the construction project management software that the survey respondents use. An explanation is that scheduling and

budgeting software are often separate software and have not yet integrated successfully with software that account for other construction aspects such as labor force safety.

The second most frequent answer in this question was the option “Other”, which generated many customized responses. As expected, the integration of the software is being sought by employees in construction companies. For example, one respondent quoted “We have developed a best of brand mentality as we understand that no software will integrate exactly the way we want. So we have ProCore for Project Management, but utilize P6 for schedule, Timberline for project cost accounting, Sage for estimating.”. This response reflects a situation where integration of construction aspects is not successful and results in companies using multiple software for each construction aspect. This lack of integration is further shown in answers such as “Each specific software is great for its design, but would be great if they integrated better. Plus different clients require different software, so you need to be proficient in programs that are basically the same”.

According to the answers in Question 7, we can infer that not only the scheduling and budgeting software should be improved and be better implemented into construction companies but also the integration of multiple software. Thus, we expect these three answers to be frequent in Question 8. Lastly, just 5 survey respondents (13%) reported that the software that they are using is extremely convenient.

4.5 Construction Aspects that Lack Innovation In Technology

This section will present the answers that were given to Question 8, "Which aspect of construction do you believe lacks innovation in technology?". **Figure 4.5.1** demonstrates the construction aspects that the survey respondents believe that require technological advancement. As mentioned above, we expect to see similar construction aspects with the ones that the employees that participated in the survey reported that were not satisfied in Question 7.

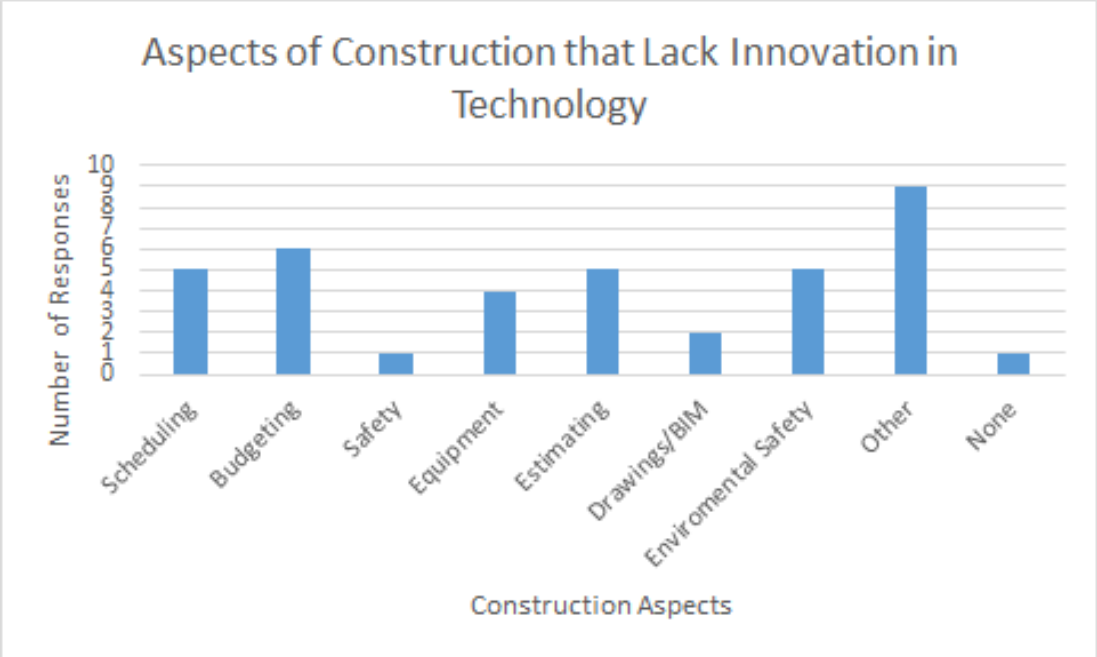

Figure 4.5.1 : Aspects of Construction that Lack Innovation in Technology

In the bar chart above, with a total of 38 respondents, "Other" was the dominant choice; this option required a written response. One respondent who selected "Other" commented "Integration of all these." Also, "Budgeting" and "Scheduling" were also ranked as 2nd and 3rd respectively. However, one can say that the responses were distributed among all the answers.

Considering the diverse range of answers, it can be inferred that there is not one aspect of construction that lacks innovation in technology significantly to a different one.

Another "other" response that was recorded was, "I believe there is software that is great for nearly everything involved in the construction industry, but these technologies have significant costs. Most of them provide a benefit that outweighs their cost, but many owners are reluctant to pay for the upfront costs. We have found the North East region clients tend to push-back on the cost of technology, compared to the west coast that embraces it." In fact, our survey was sent to employees that worked only in the Northeast region but this subject will be further mentioned in **Limitations 6.0.**

Taking into account that not one specific aspect of construction lacks innovation more than another, it can be inferred that the price of such technologies is a possible reason for the lack of innovation in most construction aspects.

4.6 Factors of Success in a Construction Project

Question 10 asked the survey respondents "What two measures do you consider most important when evaluating the success of a project?". The respondents were asked to pick two factors but were not limited in their options. **Figure 4.6.1** demonstrates the factors that employees value the most after the completion of a construction project.

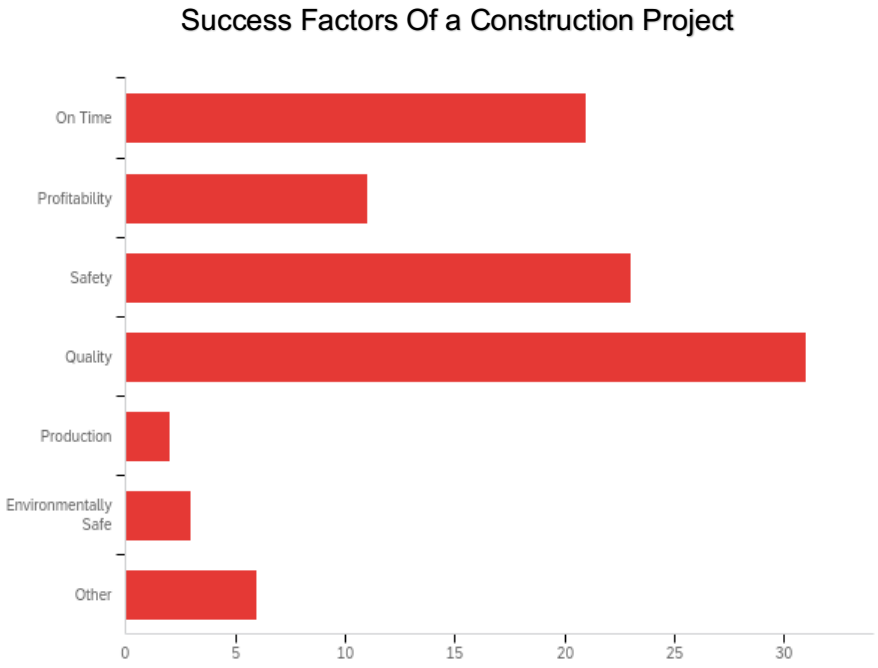

Figure 4.6.1 Factors that Define the Success of a Construction Project

It is clear that the quality of the final project is what most employees believe that defines a successful project. In fact, 31 of the respondents picked "Quality" which consists of more than 75% of the sample. Owners are always concerned with the quality of the project, so it is reasonable for employees to prioritize quality as a success factor.

The survey respondents picked “safety” 23 times (56%). This factor implies that the construction project is completed without having anyone injured on-site. As described in **section 3.4.1**, safety is a very important aspect of the construction industry and this question’s results verify it.

The third most frequent was “On time”. This reflects the accurate follow of the planned project scheduling. The importance of scheduling is mentioned extensively in **section 3.4.3**. More specifically, the evolution of construction management software has significantly improved the efficiency of scheduling tools. The significance of scheduling is confirmed by the participants of this project’s survey.

The responses of Question 10 suggest that construction companies should prioritize quality, scheduling and safety when choosing the appropriate software for their business. This statement will be further discussed in **Recommendations 5.0.**

5.0 Recommendations

5.1 Selecting the Most Appropriate Construction Management Software

Based on our research and findings, our team has concluded that there is not one "best" project management software or technology that should be used for every commercial construction company. Instead, each individual company needs to find which software is most suitable for them and would help their company become the most efficient and successful as possible. Companies should not be settling to use the software or programs that they have been using in the past because they are fearful of a stressful transition period or a more expensive program. As found in our analysis, employees are not necessarily disappointed in their company's software, but an overall satisfaction of 6.65 proves that a better suited technology for the company can be found. Business management needs to be open to studying the new technologies and discovering if there is a better software for their company's processes that will help their construction management become more efficient in the long run.

The reason there is not one best software or one correct choice for the whole industry is that each company has different business needs. More specifically, commercial construction companies are different in their size, vision, specialties, organizational structure and processes. A company that constructs work globally and has tens of thousands of employees that specializes in healthcare will most likely have different needs than a company that has hundreds of employees, only does work in one region, and specializes in education. This is why each individual company must do the proper research to decide which software will work best for their company's goals

and employees. For instance, based on our analysis, ProCore is by far the most commonly used PMS from the survey results. However, the range of satisfaction from the employees is 4-9 out of 10, with the average being a 7. For some companies, ProCore may be a perfect fit and the employees may give it an 8 or 9 out of 10. For others, it may not be a great fit leading to their employees rating it a 4 or 5 out of 10. This is why these companies should do research both internally and externally. Internal research, such as an internal survey, will give management an idea of the company's needs from the top of the organization down to lower levels and it will provide feedback from the employees on what they need to do their job successfully. External research, such as an industry analysis, will give the company an idea of what similar companies are using and if it has been successful or not. It also will provide information on the available technologies and what benefits each software offers. In order to do this, our group came up with a process that commercial construction companies can follow to assist them in choosing the appropriate software for their company.

5.2 Internal Investigation and Analysis

The first step in this process is the internal investigation and analysis. One must study his or her company first to get an in-depth understanding of what the company needs in terms of software and technology to make it more successful. In order to do this, one can hold internal meetings/interviews and conduct internal surveys to get feedback from the people working in the company and using the current software. This internal study should give management a good idea of how the employees feel about the current software being used. They will explain what is good and what needs to be improved or added. This will show what the employees' recommendations are and what their satisfaction is of the software being used.

5.3 External Research - Industry Analysis

The next step is to conduct external research on the commercial construction industry and on the different available project management software. When studying the construction industry, one should research the competitors and discover who has been successful, who is trending in the right direction, and who is failing. Once the data is collected, one should look at the companies who are similar in size, specialties, and processes to your company. Studying what similar companies use will enable the buyer to understand what is helping these companies succeed or what is causing them to fail.

5.4 Selecting Decision Criteria

Based on the industry analysis and what has been learned from studying similar companies, one should create a list of products that he or she wants to obtain more information on. Along with this, a criterion should be developed that will help in the decision of which software best fits the company. This criterion should be based on the internal and external research that has been conducted. For instance, if one finds that the company's employees are looking for more advanced technology in scheduling or budgeting, or a software that integrates these aspects of construction, then this should be a part of the decision criterion. Other items that should be considered are functionality, ease of use, customer service, special features, and the cost. A larger emphasis should be placed on the aspects that each company values the most. Based on our analysis, the top factor when determining the success of a project is quality, followed by safety, meeting deadlines, and then profitability. If the relevant company has similar beliefs on success factors, the cost of the software should not be the top priority when deciding on a

product. Since quality seems to be the most important, then the features of the software should hold a larger weight in the criterion than the cost. Once the appropriate criteria are developed, one will be able to narrow down the options from the many different available PMS.

After narrowing down the options, one will want to reach out to the vendors that are selling these products. Meeting with these vendors will provide more information on their products and will also allow one to understand the demo processes that they offer. Many of these vendors allow companies to demo their products before the purchase. Once the demo has been finished, one should then analyze which software is the best for his or her business.

The demo approach is not the goal of this recommendation but is an opportunity that should definitely be taken advantage of so that members of the company can test out the potential products before any investment has taken place. It will give a better understanding if the software fits the criterion that each company has created.

5.5 Implementing the Project Management Software

Finally, once the management team is able to discover which software is the best for the company, it should develop an implementation plan to ensure a smooth transition. This process usually takes anywhere from 0-6 months (O'Loughlin, 2019). One must have the proper training for the company's employees so that they are able to easily use the different features of the software which influenced the decision of the PM software purchase. Although it may be frustrating at first it is probable that there will be an adjusting period. If one company does the proper research and supports its purchase decision, the chances of improving the efficiency of its construction management are significantly increased.

5.6 Viability of Proposed Recommendations

The recommendations of this project are considered technically, organizationally and financially viable.

5.6.1 Financial Viability

The proposed recommendations require the dedication of resources such as money and time in order for companies to reach the best decision. As mentioned in **section 5.1**, each company should act according to their business needs. Each company should conduct a cost-benefit analysis. This project suggests that the functionality and quality of PM software are more important qualities than the price of the software. The recommendations of this project can be used both by low budget construction companies and wealthy multinational construction companies. More specifically, the low budget company would perform internal and external analysis that would not require additional costs. Such analysis would involve internal surveys and external online research that are similar to this project. Bigger companies can employ consulting companies that will help them perform a very detailed and accurate industry analysis. Either way, the benefits of such analysis will outweigh the costs, if any, in the long term as employees increase their construction management efficiency.

5.6.2 Organizational viability

The proposed solution of this project is aligned with the business strategy of every commercial construction company. A stakeholder analysis will show the benefits of the proposed solution, given that it is successful, to all stakeholders involved in a construction project. Choosing the most appropriate PM software will increase the efficiency of various construction aspects. Internally, the construction company will face more efficient construction management. The efficiency of construction management will bring both short and long term benefits. These benefits include an increase in the employees' satisfaction and improvement in internal and external communication among construction companies' employees, project owners, subcontractors and the rest of the stakeholders.

5.6.3 Technical viability

The project size varies depending on the size of the company and the resources that it is willing to devote. The technical risk in the proposed solution is the probability that the PM software that was purchased turns out to be the wrong decision. The steps that are proposed to follow encourage the use of demos and tutorials before the purchase of the PM software that minimizes the probability of selecting a software that is not liked by the company's employees. However, external stakeholders of the company such as subcontractors might not be familiar with the PM software that the company has purchased. This situation can lead to inefficiencies in construction management but more importantly to a lack of interoperability between the participating companies involved in a construction project. Thus, it is very important for these companies to

conduct an accurate industry analysis, as proposed in **section 5.3**, in order to avoid technical inefficiencies between companies.

Lastly, construction companies are adapting to new technologies, such as PM software, that aim to improve construction processes. Employees in the commercial construction industry have to become even more familiar with these new technologies. The proposed solution will not only improve the efficiency of construction management but also increase the familiarity of the company's employees with new technologies in the construction industry.

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6.0 Limitations

Throughout this project the research had to be significantly narrowed down in order to focus on one specific industry. Research was performed mainly through Google Scholar and the WPI Library's website. The information was taken mostly from academic journals, government websites and professional societies.

The conducted survey was limited to obtain the maximum responses. To ensure the survey would only take 2-3 minutes, it was limited to 10 questions. In order to retrieve the most accurate and straight forward answers the questions asked were mostly multiple choice and provided the reader with a "write-in" option if needed. Questions were about 1-2 sentences long and asked specifically about the respondent's individual experience. This was done to make it easier on the respondent, allowing for less thinking and a higher percentage of responses.

The survey was anonymous and was sent only to WPI alumni. The reason it was anonymous is because there was no permission from the respondents to use their names. In order to get their permission they would have had to sign a waiver through the school. A respondent revealing their name could also lead to revealing the company they work for.

Finding the right people that were willing to participate in the survey proved to be difficult. WPI alumni were chosen as the ideal survey participants. This was assuming alumni would be more willing to participate to benefit their school and they were easier to contact. The sample was retrieved through WPI's Executive Director of the office of Lifetime Engagement for Alumni Parents and Friends, Peter Thomas. He provided a sample of alumni who had been in the

construction industry for at least 10 years. Most of the alumni currently work in the Northeast region.

Due to the fact this was an online survey sent to about 80 alumni it had to be distributed via email. Not all alumni still use their university email therefore we could not guarantee that all recipients saw the survey. One individual explained in his response that the west coast is more likely to embrace the transition into new technologies whereas the northeast tends to push back due to price.

As this research involved humans, there was expected variability in how respondents viewed the survey questions. Some chose to skip questions; others provided detailed answers. Question 5 asked the individual to select all the software they have used. Question 6 asked about their satisfaction on the software. Considering multiple people selected multiple software but were only able to select one overall number to rank, it was assumed the selected rank number was for all the software the individual used. Question 4 of this survey asked what types of projects the individual had the most experience with. The provided option "other" did not have the "write in" option which limited the feedback.

The choice "other" presented outliers and proved to be a common response for many questions. Question 9 of this survey was more complex and also did not have the option to write in if "other" was selected. When writing in a response, individuals' answers typically varied. Written responses made it difficult to hypothesize because of the significant amount of differing answers.

Appendix

A. IRB Form

WPI IRB Application

Updated By: Shannon Hynes06-Dec-2019 06:12:48 PM

GENERAL INFORMATION

APPLICATION TYPE

Record #: IRB-20-0289

* What type of application are you submitting?
Exemption Application for student project involving minimal or no risk

* There are 3 application types available

Use this application for student projects involving interviews, surveys, focus groups, observation of public behavior or benign behavioral interventions, where there is minimal risk to research subjects. "Minimal risk" means that the risks to research subjects are no greater than those ordinarily encountered in daily life. Benign behavioral interventions include testing on-line games, websites and other behavioral studies that are brief, harmless, and could not be embarrassing or offensive. (This exemption is not appropriate for studies that involve survey/interviews of children. Please select the standard application.)

* Is this a student project?
☑ Yes ☐ No

* Student project type:
Undergraduate project (MQP, IQP, Suff., other)

* (Specify):
MQP

* Title of Study
The Practices and Success Measures in Residential Construction Management in the United States from 200-2025.

* Locations of Research: *(If at WPI, please indicate where on campus. If off campus, please give details of locations.)*
We will be sending out emails from the WPI library to construction companies throughout New England.

Anticipated Dates of Research:

* Start Date: 10-Dec-2019

* Completion Date: 22-Dec-2019

* **Which of the following categories best describes your study?**
Social Sciences, management and other non-biomedical disciplines

* **Purpose of Study:**
(Please provide a concise statement of the background, nature and reasons for the proposed study. Insert below using non-technical language that can be understood by non-scientist members of the IRB.)
We are surveying people in the construction industry to identify how much modern technology they use in their work.

* Has an IRB ever suspended or terminated a study of any investigator that will be listed on this protocol?
☐ Yes ☑ No

Please indicate if your study involves:

* Investigational drugs or investigational medical devices
☐ Yes ☑ No

* Hazardous Materials
☐ Yes ☑ No

* Special diets
☐ Yes ☑ No

* Collaborating Institutions: *(Please list all collaborating Institutions.)*
none

FUNDING INFORMATION

FUNDING INFORMATION

How will the study be funded?

- ☐ Grant/Contract/Subaward (Federal)
- ☐ Grant/Contract/Subaward (Non-Federal)
- ☐ Departmental funds
- ☐ Faculty start-up or incentive funds
- ☐ Investigator out-of-pocket
- ☑ No funding anticipated

STUDY PERSONNEL

All study personnel having direct contact with subjects **must** take and pass a training course on human subjects research. There are links to web-based training courses that can be accessed under the Training link on the IRB website https://www.wpi.edu/research/support/compliance/institutional-review-board.

Name
Bitsos, Andreas

Involvement Start Date	End Date	Role
03-Dec-2019		Student Investigator

Please upload a copy of your relevant HS training certificate(s):

Name
Doherty, Louis

Involvement Start Date	End Date	Role
03-Dec-2019		Student Investigator

Please upload a copy of your relevant HS training certificate(s):

Name
Hynes, Shannon

Involvement Start Date	End Date	Role
03-Dec-2019		Student Investigator

Please upload a copy of your relevant HS training certificate(s):

Name
Wisniewski, Jacob

Involvement Start Date	End Date	Role
03-Dec-2019		Student Investigator

Please upload a copy of your relevant HS training certificate(s):

Name
Wulf, Sharon A

Involvement Start Date	End Date	Role
03-Dec-2019		Principal Investigator

Please upload a copy of your relevant HS training certificate(s):

STUDY INFORMATION

* Expected Research Subjects:
(e.g. museum visitors under the age of 12)
Individuals that have been in the construction industry for at least 5 years.

* Project Mission Statement and Objectives:
We will evaluate the current implementation of construction technologies and their benefits. We will then make predictions on future trends in the construction industry.

* Brief Methods Listing:
(e.g. "Survey of public to ascertain knowledge and opinions about climate change" or "Interview of professionals working on climate change regarding effective city climate change program")
Survey of construction engineers and their experience and familiarity with modern construction technologies.

* Does the proposed research involve vulnerable research subjects?
(e.g. children, prisoners, students, persons with mental or physical disabilities)
☐ Yes ☑ No

* Does the research involve human subjects in ways other than as participants in interviews, focus groups, or surveys?
(e.g. observation of public behavior, use of archived data or experimental procedures)
☐ Yes ☑ No

* Will the researchers collect information that can be used to identify the subjects?
☐ Yes ☑ No

* Could the disclosure of a human subject's identity and responses place the subject at risk of criminal or civil liability or be damaging to the subject's financial standing, employability or reputation?
☐ Yes ☑ No

* Will the researchers disclose the identity or the individual responses of any human subjects?
(e.g. by quoting an individual, whether or not identified by name or title)
☐ Yes ☑ No

Appendix 1

Attach the statement of research methods or draft methodology chapter:

Attach a draft of surveys and/or a list of questions to be used for interviews or focus groups:

If sample questions are included in Appendix 1, Methodology chapter, indicate the page numbers here:

INVESTIGATOR'S ASSURANCE

All participants in this research project are agreeing to abide by the following instructions:

* ☑ You agree to inform subjects orally or in writing that:
  - Participation in the research is voluntary.
  - Participants may end their participation at any time.
  - Participants need not answer every questions in an interview or suvey.

* ☑ If your research is **anonymous**, you also inform subjects that you are not collecting names or any identifying information from them.

* ☑ If your research is **confidential**, you inform subjects that no identifying information will be disclosed with individual responses.

* ☑ If your research is **NOT** completely anonymous and confidential, you must obtain each subject's permission to publicly disclose his or her identity and/or responses. All requests for anonymity and confidentiality must be honored. The subject must be offered the opportunity to pre-approve the publication of any quoted material.

* ☑ I certify that I have added all Study Personnel, including students, to the study personnel page.

Appendix 1

EForm Name: IRB Application
Page: Study Information
Section:
Question: Attach the statement of research methods or draft methodology chapter:
File Name: Methodology.docx

Methodology – IRB Form

Andreas Bitsos
Lou Doherty
Shannon Hynes
Jake Wisniewski

This project examines the evolution of construction project management practices over the recent years and its goal is to emphasize the development of technological advances in various construction processes. The development of this project required the use of several research methods that aimed to produce valuable data that fit our needs. This section will describe the process of obtaining the information that is related to our project.

Internal group communication of the group was done mainly through texts and emails. Our files were organized and accessed through Google Drive which all team members shared. The delegation of tasks among team members and efficient scheduling was important for the development of our project. Various meetings were scheduled via email and Microsoft Office Calendar was used to check availability. For internal scheduling purposes, the team developed a Gantt chart which demonstrated internal deadlines that were set among the MQP members.

After deciding on the subject of our project, our first step was to broadly research the construction industry in order to get a better understanding of it. Our research was performed through academic journals, government websites and professional societies such as the American Society of Civil Engineers (ASCE). These were found mostly through the use of the Google Scholar search engine.

Our group decided that our research on the literature review should be enriched and become more scoped in terms of the industry, the aim of the project and the time of the published journals. We scheduled a meeting with WPI librarian (Gordon C. Library) Laura Robinson in order to improve our researching skills and methods. Our research was expanded through engines such as IBIS World and Business Source Elite which we had access through the WPI library. IBIS world guided us on the North American Industry Classification System (NAICS) and Standard Industrial Classification (SIC) which

helped us define the industry that we have focused. These two classification systems contributed on our research by filtering our search engines with the respective industry and thus providing more scoped out results.

Even though online research is very important for the development of the literature review, the group decided that sending out a survey would give us more insight on the research topic. The next step was to schedule a meeting with WPI's *Executive Director of the Office of Lifetime Engagement for Alumni Parents and Friends*, Peter Thomas. A confidentiality agreement was signed from the group members concerning the data. Our main topic was the sample that would receive the survey questionnaire. Our request involved obtaining contact information from WPI alumni that work in the following construction companies: Shawmut Design & Construction, Turner Construction, Suffolk Construction Company, Consigli Construction, Gilbane Building Company, Bond Brothers, Callahan Construction, Whiting Turner, Crenshaw Construction. These companies are frequent destinations for WPI alumni.

The intended sample size of the survey is 97 WPI alumni and the software to be used is Qualtrics. 11 questions are to be asked and the expected survey time should not exceed 2 minutes. The purpose of the questions that we desire to include in the survey instrument is to get a better understanding of how technology is being implemented into these employee's jobs and decide on which construction aspects have the most room for technological innovation. These questions will enrich our knowledge on the trends and culture that some construction companies are trying to impose on this modern era.

B. Survey Instrument

Q1.
Job Title:

Q2.
Your company size:

- <50
- 50-250
- 250-500
- 500-5000
- >5000

Q3.
How many years have you been with this company?

Q4.
Choose the type(s) of projects you have the most experience working on?

- Commercial
- Residential
- Government
- Healthcare
- Education
- Industrial
- Infrastructure
- Other

Q5.
Do you use a Project Management Information Software in your company? If Yes, please state the name of the software.

Q6.
How satisfied are you with the ability of this software to integrate several different aspects of construction management? (Scheduling, Budgeting, Change Orders, Manpower, Equipment info, etc)

Not satisfied at all								Extremely satisfied		
0	1	2	3	4	5	6	7	8	9	10

Q7.

Is there an important aspect of construction management that this software does not account for which makes it inconvenient?

- ○ No, this software is extremely convenient!
- ○ Scheduling
- ○ Budgeting
- ○ Labor Force
- ○ Equipment
- ○ Change Orders/RFIs
- ○ Drawings
- ○ Other _____

Q8.
Which aspect of construction do you believe lacks innovation in technology?

- ○ Scheduling
- ○ Budgeting
- ○ Safety
- ○ Equipment
- ○ Estimating
- ○ Drawings/BIM
- ○ Environmental Safety
- ○ Other _____
- ○ None

Q9.
Does your company experiment/use any of the following technology to improve in any of the categories listed below?

	Safety of Workers (1)	Environmental Safety (2)	Scheduling Efficiency (3)	Other (4)
Drones (1)	☐	☐	☐	☐
3D Printing (2)	☐	☐	☐	☐
3D Scanners (3)	☐	☐	☐	☐
Virtual Reality (4)	☐	☐	☐	☐
Augmented Reality (5)	☐	☐	☐	☐
Wearable Devices (6)	☐	☐	☐	☐
Automated Digital Labor (7)	☐	☐	☐	☐
Other (8)	☐	☐	☐	☐

None (9)	☐	☐	☐	☐

Q10.
What two measures do you consider most important when evaluating the success of a project?

- ○ On Time
- ○ Profitability
- ○ Safety
- ○ Quality
- ○ Production
- ○ Environmentally Safe
- ○ Other _____

C. Survey Email

Dear WPI alumni,

We are a team of 4 senior students from WPI working on our Major Qualifying Project (MQP). Our MQP is focusing on how technology is being incorporated in the practices and success measures of construction management over the last 20 years. We are sending out anonymous surveys to WPI alumni with all levels of experience in the construction industry to gather data on how technology has been used over the years.

Our mission is to analyze the data we gather in order to better understand the trends and methods that modern construction companies are trying to impose. Survey data will be used only for MQP purposes and personal information will be deleted with the completion of the project.

We understand that you are busy. The survey is **Mobile Friendly** and should not take longer than **2 minutes.**

Thanks,

WPI MQP Team

Survey URL: http://wpi.qualtrics.com/jfe/form/SV_eDatf1AInLCoyIB

D. List of Companies (Survey)

Consigli Construction Company, Inc.

Gilbane Building Company, Inc.

Kirchhoff - Consigli Construction Management

Shawmut Design & Construction

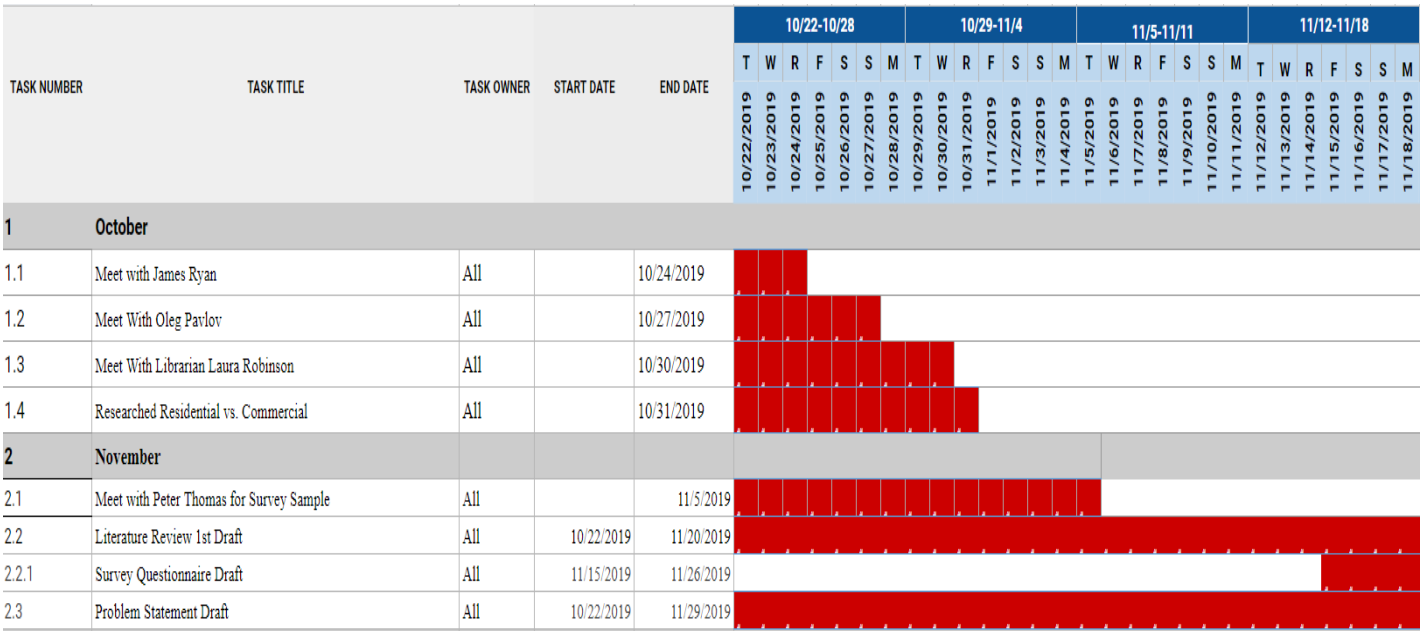
Suffolk Construction Company, Inc

Turner Construction Company

Whiting - Turner Contracting Company.

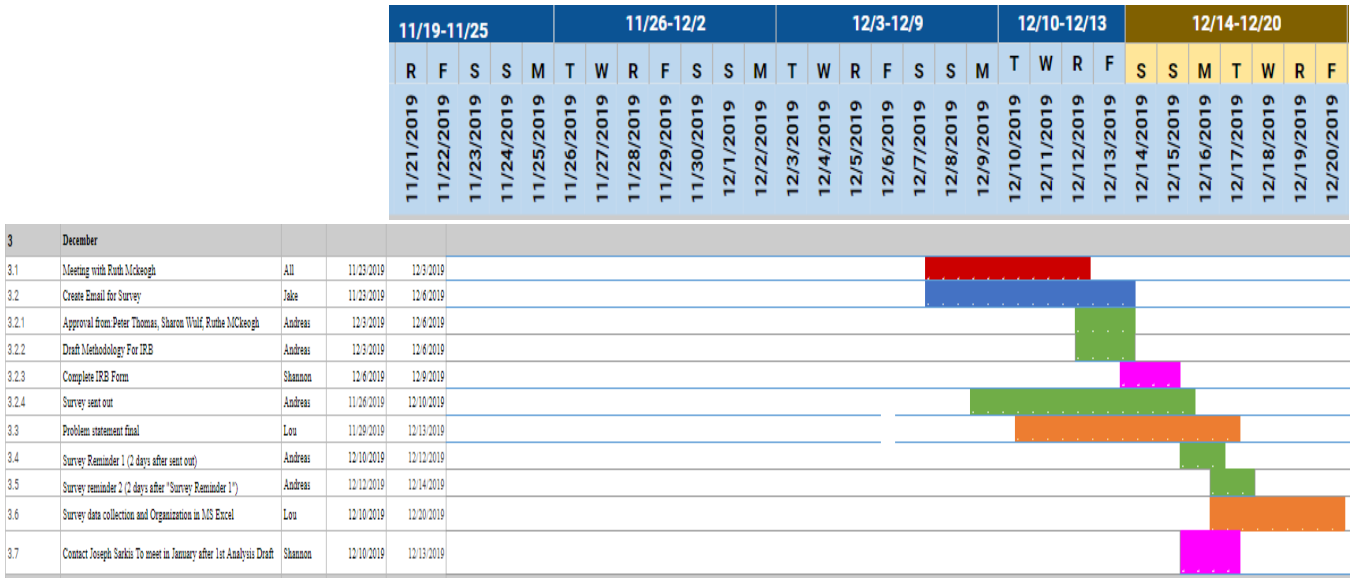
E. Gantt Chart

The red coloring means all group members participated in the task.



TASK NUMBER	TASK TITLE	TASK OWNER	START DATE	END DATE
1	October			
1.1	Meet with James Ryan	All		10/24/2019
1.2	Meet With Oleg Pavlov	All		10/27/2019
1.3	Meet With Librarian Laura Robinson	All		10/30/2019
1.4	Researched Residential vs. Commercial	All		10/31/2019
2	November			
2.1	Meet with Peter Thomas for Survey Sample	All		11/5/2019
2.2	Literature Review 1st Draft	All	10/22/2019	11/20/2019
2.2.1	Survey Questionnaire Draft	All	11/15/2019	11/26/2019
2.3	Problem Statement Draft	All	10/22/2019	11/29/2019

The blue coloring is tasks done by Jake Wisniewski. The green coloring is tasks done by Andreas Bitsos. The pink coloring is tasks done by Shannon Hynes. The orange coloring is tasks done by Lou Doherty.



3	December				
3.1	Meeting with Ruth Mckeogh	All	11/23/2019	12/3/2019	
3.2	Create Email for Survey	Jake	11/23/2019	12/6/2019	
3.2.1	Approval from Peter Thomas, Sharon Wulf, Ruthe MCkeogh	Andreas	12/3/2019	12/6/2019	
3.2.2	Draft Methodology For IRB	Andreas	12/3/2019	12/6/2019	
3.2.3	Complete IRB Form	Shannon	12/6/2019	12/9/2019	
3.2.4	Survey sent out	Andreas	11/26/2019	12/10/2019	
3.3	Problem statement final	Lou	11/29/2019	12/13/2019	
3.4	Survey Reminder 1 (2 days after sent out)	Andreas	12/10/2019	12/12/2019	
3.5	Survey reminder 2 (2 days after "Survey Reminder 1")	Andreas	12/12/2019	12/14/2019	
3.6	Survey data collection and Organization in MS Excel	Lou	12/10/2019	12/20/2019	
3.7	Contact Joseph Sarkis To meet in January after 1st Analysis Draft	Shannon	12/10/2019	12/13/2019	

F. Gantt Chart Function

(IF(AND(J$11<=$F13, J$11>=$E13), (IF($D13="All", "Al", IF($D13="Shannon", "Sh",

IF($D13="Jake", "J", IF($D13="Andreas", "A", IF($D13="Lou", "L", "")))))), ""))

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