Project Number: GFS-0711

PROJECT INTEGRATION ANALYSIS AND VALUE ENGINEERING STUDY FOR THE NEW WPI RESIDENCE HALL

A Major Qualifying Project Report:

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Heather M. La Hart

Date: April 26, 2007

Approved:

Professor Guillermo Salazar, Advisor

ABSTRACT

A project integration analysis and value engineering study were conducted during the design phase of the new WPI Residence Hall building. Project integration factors were ranked according to their usage and importance levels and compared through a Pearson Correlation. Also identified were areas to increase integration and grouped data into categories to identify any biases. The value engineering study performed after conceptual and design development stages identified 5% potential cost savings. The project examined the benefits and limitations of project integration and value engineering as modern management and engineering tools.

CAPSTONE DESIGN STATEMENT

The budget for the new WPI Residence Hall that is being built is being monitored and managed by the Construction Manager Gilbane, the Designer Cannon Design, and the owner's representative Cardinal Construction. Each party has been developing their own estimates for the project. The teams utilized value engineering during the schematic design phase but did not use it in either the conceptual design phase or the design development phase of the building.

To address this issue, a value engineering study was performed after the conceptual design phase and then again during the design development stage of design for the new WPI Residence Hall. The conceptual design value engineering study looked at three different alternatives and through a life cycle cost model determined which alternative would provide the most reduction in cost. Since after the design development phase of design there is more information available more models can be constructed and used to develop better results. After the Design Development phase of design was complete a value engineering study was performed that used space, energy, and construction cost models after a function analysis in order to determine the cost savings created by the study.

The value engineering studies for the new WPI Residence Hall looked at the core economics of the building and the various ways that altering certain aspects of the building could affect it in the present and over its lifetime. In order to address the environmental concerns of today, the new WPI Residence Hall is attempting to become a silver LEED (Leadership on Energy and Environmental Conservation) certified building. The value engineering study was performed with environmental concerns by taking into consideration the LEED certification and also looking at ways to create a more energy efficient building while maintaining value. The sustainability and manufacturability of the building is optimized by performing a value engineering study because it determines ways to provide the same function and value for the building over time but in a more cost effective manner. The value engineering studies that were conducted for the new WPI Residence Hall provided economic and environmental benefits, demonstrated how developing value engineering studies can impact a project, and showed how the more involvement of all of the parties in a project can produce more effective results.

ACKNOWLEDGEMENTS

I would like to thank Worcester Polytechnic Institute for making such an opportunity like this one possible for me and providing me with a great experience as an undergraduate here. I would also like to thank my advisor, Professor Guillermo Salazar, for all his guidance, advice, support, and ongoing contributions to my academic experience and life which led me to conducting this research paper. I would also like to thank Professor Arthur Heinricher from the Mathematical Science Department for helping me along with Professor Guillermo Salazar to come up with a research area which I could both apply my skills I have learned from my math major and my civil engineering major. I would also like to thank the WPI Residence Hall Committee, especially Lynn and Neil from Canon Design, Bill from Gilbane Building Company, and WPI for their ongoing support and openness for answering questions and providing any information that was needed to complete my research. I would like to thank also my parents for their wonderful support throughout my time here at WPI. I would also like to thank my boyfriend Patrick Tierney for his ongoing support and patience throughout the duration of this project. Overall, I would like to thank anyone and everyone who helped to make this research project successful.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1 INTRODUCTION

The architecture/engineering/construction (A/E/C) industry is highly fragmented and there exists a high degree of specialty, a large diversity and thus a high demand for integration among all parts of a project including people, product, and process. How information is exchanged, projects monitored, and products transferred & produced have a large effect on a variety of factors of a project. The A/E/C industry has approached dealing with these issues is through developing various project delivery systems, using project models to gauge progress and information, and qualitative studies analyzing the value of different project methods.

The main concerns of a project are time, cost, and quality and they each affect one another. As the complexity of construction projects increases along with the demand for better, faster, and cheaper projects there is an incessant need for an integrated model to demonstrate how to achieve these demands. There are a variety of project delivery systems that provide an ample approach to meeting these demands. It has been demonstrated through research although that a project delivery system which is a more integrated project results in all around better results in quality, time, and cost of a project, although there currently exists no way to quantitatively measure or place value on the impact of project integration. Thus having an informational model which could represent the integration of a project could dramatically influence and change the way that projects are conducted, monitored, and managed.

This research was conducted in conjunction with a mathematical research project as a means to identify and measure project integration. A case study of the new WPI Residence Hall was conducted in order to identify factors of integration, perform a value engineering analysis, and to extract necessary data to be input into the model developed by the mathematical research performed in conjunction with this research. The results of this research aim to help understand the how to identify & quantify factors of project integration and the effects that integration has on projects which can then be applied to a mathematical model representative of project integration to ultimately provide the A/E/C industry with a way in which project integration can be measured [16].

This report is broken down into five main sections. Section 2: Background provides an overview of the different project delivery methods that can be used for a project, what is project integration and how it can be identified, a description of different informational models used in the A/E/C industry, and then an overview of value engineering and analysis.

Section 3: Methodology discusses the way in which data was obtained and measured for the investigation and analysis of project integration and the value engineering design and analysis for the capstone design requirement. The section provides an overview of project integration and factors of project integration were identified, how the project, process, product, and organization models are applied to projects, how value engineering can be applied to projects, and an overview of the mathematical research that was done in conjunction with this project was provided.

Section 4: Investigation and Analysis provides a presentation of the results of that data in relation to the methods presented in Section 3. Here an analysis of the different information models was performed along with an analysis of the integration found in the project, followed by a value engineering analysis of the WPI Residence Hall, and then to conclude with the results of the Mathematical research that was being conducted in conjunction with this research put together with the Civil Engineering research as a means to provide an analysis of the project integration involved in the project.

Section 5: Conclusions takes the data results and analysis from Section 4 and presents how the information from the project integration model and value engineering analysis can be used to provide a measure for how integrated a project is and how value engineering can be an effective form of analysis in order to provide a more efficient project in terms of time, cost, and quality.

Section 6: Future Recommendations is the last section of the paper and describes what further research can be conducted in order to provide a further understanding of project integration methods and how to further develop the project integration model that was developed and presented in this research.

2 BACKGROUND

The way in which a project is carried out, the way tasks are distributed amongst parties and the analysis of the various factors of a project all ultimately affect the success of a project. In order for a project to be successfully executed a proper execution of all the various responsibilities, tasks, and parties of a project need to be coordinated effectively.

The project delivery system that is chosen for a given project relies heavily on how the tasks and responsibilities of that project are distributed. Understanding the exchange, collection, and ongoing actions of tasks, parties, and responsibilities is best achieved by creating and dissecting informational models. There is almost no project that is finished with out any problems but a variety of issues in construction projects can be reduced through the integration of all aspects of the project [4].

2.1 PROJECT DELIVERY METHODS

Project delivery systems provide owners the ability to choose different ways to carry out a project as a means to meet their specific requirements of value in cost, quality, service and technology. There is no clear cut choice in which is the right selection of a delivery system, but the requirements of each individual project and the expectations of the owner are usually which serve as indicators for which delivery system would be most effective & successful. Each delivery system has a different approach to the process of construction projects, different characteristics, and positive and negative aspects. Design/Bid/Build, Design/Build, and Construction Management are three of the most popular project delivery method and each possess varying characteristics from one another [6]. In determining which delivery system is right for each project an owner needs to consider a variety of factors like unpredictable conditions, possible design changes, time and cost constraints, risk, workforce issues, number of contracts, selection criteria, relationship of owner to contractor, and terms of payment. Even though the selection of the project participants and then carefully implementation of a project are important, ultimately it is the selection of the best possible project delivery method that is critical [7].

2.1.1 Design/Bid/Build

Throughout the post-World War II era the primary delivery system that was used in America's infrastructural development was design/bid/build (DBB). This type of delivery system is primarily used in projects with a well defined scope, primary focus on cost, and a secondary focus on schedule. There are three parties involved the owner, designer, and contractor. This method is often referred to as the traditional project delivery method because all design work is completed before starting to bid and construction. There are three steps within this process, design, bid, and build. First a design is prepared by the designer (aka architect), followed by a competitive bidding process from contractors, then to the final step with the award of a contract to a contractor to construct the project. The architect and the contractor receive separate contracts. The DBB method is a three party arrangement which involves the owner, designer, and contractor. [6].

There exist several strengths for DBB besides the fact that it is the most established and familiar form of project delivery. A benefit to choosing this method is that the owner knows the approximate cost for the project and the plan for the project before construction has started, which can be very useful especially in public projects (hence why this delivery method is mostly used in the public sector of construction). Also using this method the owner has an extreme amount of influence over the design and can easily monitor the design development process so that any adjustments the owner wants can be made during this initial design phase. A downfall to this method is that it can take a considerable amount of time because each step has to be completed before another is started. Also if there are any changes during construction it can be quite costly for the architect or contractor because most design/bid/build contracts are awarded on a lump sum or fixed price contract [6].

2.1.2 Design/Build

It has been over the past ten to fifteen years that design/build (DB) has gained strength and popularity as a project delivery method. DB continues to be more popular in the private sector than in the public sector. Design/build is a project delivery system that involves an integration of design and construction and as a result produces a reduced time schedule. It continues to be a method which is often chosen in order to decrease the amount of time to complete a project. Project completion time can be reduced because the construction phase can start before the design is completed. The owner signs a single contract which contains the architectural, engineering, and construction services all in completed by one agent [18].

The organization of a DB firm can be organized in four different ways: (1) both design and construction are in-house, (2) a joint-venture is created between the designer & contractor (3) the project is led by the contractor and the design services are contracted out (4) or the project is led by the designer and the contracting services are contracted out. Just as DBB produces a competition over the construction of the project DB projects create a cost competition over both design and construction together [7].

Just as with DBB there are both negative and positive characteristics to the project delivery method of DB. Some positive characteristics of DB is that having the contractor involved in the design can result in more valued engineered solutions for the project, the cost is transferred to the DB firm and any changes from design error or omission are removed from their finances, a highly qualified technical team, schedule reduction due to integration of design & construction, reduction in number of change orders and shop drawings, early knowledge of costs, value engineering, and continued involvement of key members of the project [7].

These advantages can be contrasted with the disadvantages that are present in DB. Some of the disadvantages of DB are the designer no longer being an agent of the owner, incomplete design & concept, less checks and balances between the owner and DB firm, higher price contingency due to possible unforeseen changes & costs, cost delays during construction because of incompletion of design tasks and/or requirements, and limited competition for bids due to the high cost of preparing proposals [7].

Thus DB as a project delivery method is effective for projects that have flexibility with their design, those that desire limited owner involvement, and where time and cost constraints are of concern.

2.1.3 Construction Management

Construction management is another type of project delivery method in addition to design/bid/build and design/build. Often a construction management contract will be awarded to a Construction Management firm in order to coordinate the project for the owner. There are four separate parties that are involved which include the owner, architect/engineer, contractor, and construction manager. There are a variety of ways that the construction management method of project delivery can be handled such as agency CM, corporate CM, and CM at risk [18].

Agency CM is often referred to in the A/E/C industry as pure CM. This form of construction management is where a CM is a firm separate from the owner and acts as an agent on behalf of the owner. The CM is has not direct involvement with the design or engineering concepts of the project but helps to assist the owner in selecting such parties as the designer and contractor. This form of CM project delivery the CM assumes no risk because all of the contracts are signed by the owner and other parties, and the CM has only one contract with the owner [18].

Corporate CM is another form of a construction management project delivery method and slightly similar to agency CM. The only difference between corporate CM and agency CM is that the CM services in corporate CM are performed by employees within the owner's organization. Yet it is similar to agency CM because the design and engineering services are still performed by firms which are outside of the owner's organization but coordinated and organized by the owner's staff [18].

The third form of construction management delivery system is CM at risk. The reason it is called CM at risk is because unlike agency CM, CM at risk the CM performs some of the project work and thus is susceptible to items such as quality, cost, and schedule. The design work could be fully included or not included at all as a task of the CM. From this two separate sub-variations of CM at risk have developed which are referred to as contractor CM at risk and designer CM at risk. Contractor CM at risk is where a construction firm primarily is concerned with the construction aspects of the project and hires a designer whereas designer CM at risk is where a design firm is the construction manager and is primarily concerned with the design aspects of the project and hires a contractor [18].

Despite which variation of CM at risk is used, CM remains to be a single source management of the project which allows the owner to decide how to control his/her involvement in the project. Early addition of the CM to the project can provide valuable information which can help produce a more successful project by increasing the potential for cost reductions through elimination of various associated administrative costs from designers and contractors. By integrating all parties from the start of the project to the end of the project there can be potential savings in cost, time, and decision making [18].

2.1.4 Project Phases

There are three main phases of a project: project definition, design, and construction. The different types of project processes tackle each phase in different ways, so there are reasons to choose one type of process over another. The first phase, project definition, sets the basics for the project defining what the project is all about including requirements, limitations, etc. Primarily the owner will come up with those but even the contractor and architect may have their own requirements and constraints for the project. In relation to project integration that is why having all parties involved in this phase provides the best strategy to optimize project integration. A collaboration of each party's ideas and constraints provides the project definition, time of the project, cost, and project delivery. Even though the selection of a project process is important, it is as or more important to select quality members of the project team because most projects are successful because of the cooperation of people on the project.

In the early stages of a project the design and completion phase. Each category of organization, product, and process each have different factors that affect project integration; identifying these factors is essential to understanding how they affect the level of integration.[1]

2.2 MODELS USED IN A/E/C INDUSTRY

Information management involves a large amount of individuals and organizations that at different times and different locations are exchanging all sorts of information. Incorporating the informational management strategy into projects especially during design and construction phases can remove constant reiteration, redistribution, and reallocation of data, and thus it encourages integration amongst design and constriction fields and therefore provides an information structure that is useful for all participants of the project [13].

Models of products, process, and projects are necessary and extremely useful to this industry as they provide the informational structure which binds everyone and everything together. These integrated models of products, process, and people encourage everyone to add additional information to the project but also provide more affluent information, consistent data, greater efficiency amongst project, and a more adaptable environment for informational exchange [4]. The research involving project integration is consistently trying to "redefine existing design processes to make them more collaborative and to develop enabling technologies to support the new process" [4]. Various research on integrated models of product and processes or processes and product has been conducted but there is yet to be a model developed which involves the integration of product, process, and people of the project which is directly integrated and attached to the cost and schedule of a project which can model how these different parts of construction if integrated with one another, affect a project.

2.2.1 Product Model

A product model is a theoretical model where all the building product information among participants of the project is organized and then structured in a way so all participants can access and add to the information. One of the first product informational models was developed in 1988 by Gielingh, called the General A/E/C Reference model. It was organized according to Product Definition Units, functional units, and their associated technical units. The following year Bjork developed the RATAS model which organized products by the composition and decomposition relationships between building components. Although one of the most recent models in product information is the STEP/PDES Model developed by NIPDE in 1995; unlike the other models this model organizes the products by standardization of computer representations and exchanges of data [4].

2.2.2 Process Model

Process models are another type of informational model used in the A/E/C industry and are used to represent the important steps throughout the duration of a project. In 1990 Sandivo developed the integrated Building Process Model which was a model based of project processes that identified essential information of a project by separating the project into five different phases or processes: manage, plan, design, construct, and operate facility, where each individual phase had additional sub-processes.

In 1992 Fisher and Yin developed a different model called the General Data-Flow Model which was based on the flow of information from a contractor's point of view [4].

2.2.3 Project Model

Project Models are another form of an informational model that reflects information about the project. These models provide an ordered structure for the product, process, and organizational (people i.e.: management) information in order to provide more information and better meaning of a project for project management purposes. The unified Approach Model developed by Bjork in 1992, the GenCOM Model by Froese in 1992, the BPM model by Luiten also in 1992, and the IRMA also developed by Luiten but in 1993 are all among the popular project models used in the A/E/C industry [4].

2.2.4 Management Model

Arkwright not only developed one of the first forms of an integrated process but he also set forth a functional organizational structure known as a 'factory' type organization. It was this structure that around 1850 spread and set a standard for the structure of management & employees of other industries and textiles. As systems and processes became more complicated as the Industrial Revolution rounded the corner so did the organizational structure of industries. Out of the concern with problems of how to organize management and operation, a field of study called organizational theory was derived. This field is concerned with the structure of an organization, the ways in which it functions and the correlated performance. The focus of attention is placed both on the individual and the group because together and separately they affect the function and performance of the organization as a whole. There are a variety of ways in which organization theory can be applied to management of a project: considering the nature of work that needs to be completed in correlation with the objectives that need to be achieved, the size of an organization and the skills of its members, the industry and the technical means of each individual, etc [5].

Due to the large amount of people involved in a project use of management or organizational models in the A/E/C industry are very helpful. One of the best ways that organizational theory, (developed by F.W. Taylor) has modeled management structure is through the use of a family tree or organized chart. This chart as seen in Figure 2-1: Example of First Organizational Tree

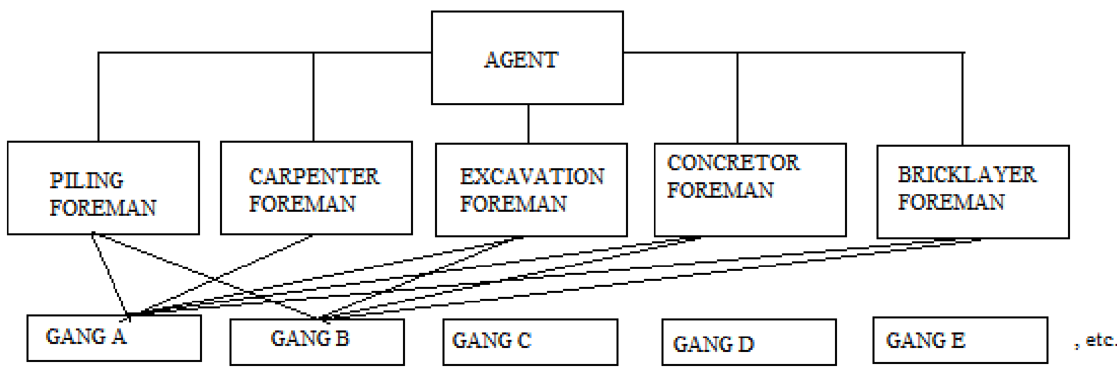


Figure 2-1: Example of First Organizational Tree

displays the hierarchy of an organization, the relationship amongst its members, and the inter-relationship of each part of its structure. Organizational charts are of best use for modeling the management structure because the ability to organize specialties and division of labor. Also upon failure within the organization it is easy to identify the problem area. A problem with this model comes out of one of its benefits, its specialization. The specialization allows for a tendency of work groups of a smaller order to have objectives different from those of the organization as a whole and thus the expectations of the management as a whole in relation to output can produce less desirable results [5].

In order to tackle the fallacy that the organizational chart can produce in dense organizational structures an organizational model which the specializations and coordinators for project work are used to provide an organizational model for projects [5]. Organizing management in this sort of nature offers adaptive and flexible measures to provide temporary assignments or issues and combines both the advantages from project organizations and those of functional organization. The use of a project manager is highly useful and increasingly common in industries now, especially the A/E/C industry. Whether dealing with the general contractor, architect, or owner almost always you will run into each agent having a project manager for the project at hand.
Using this model allows for flexibility which helps meets the demands made by changing and unstable conditions which often occurs in the A/E/C industry. An example of how this model may look is given by Figure 2-2: Matrix Organization Chart seen below.

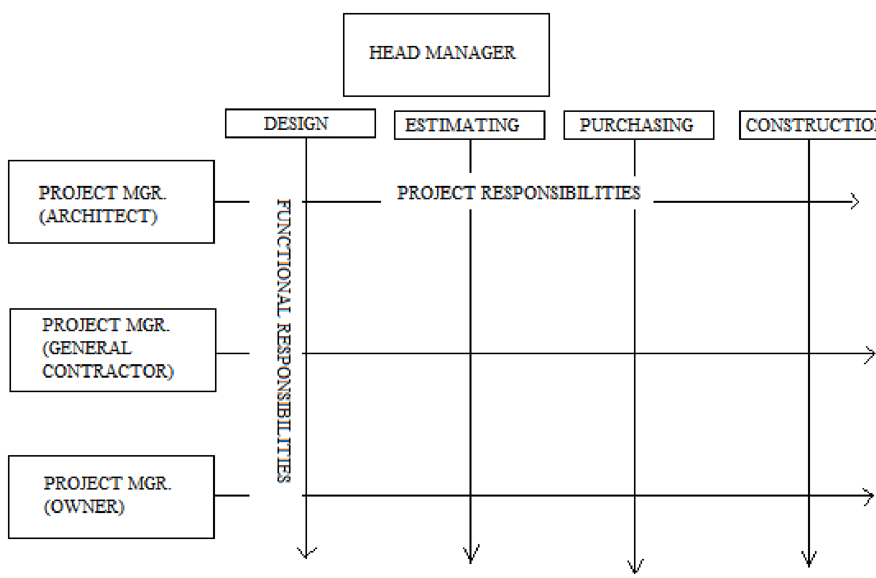


Figure 2-2: Matrix Organization Chart

Here the groups take place below the Head Manager just as they would in a functional organization chart. Although in a matrix structure each function head is capable of ensuring the excellence of his/her particular specialty and its role in the project. Thus a project manager is responsible for understanding and obtaining his contribution from each function for the project, and even though each project manager is responsible to their division head (architect, general contractor, or owner); each individual is still responsible for helping and assessing the functionality of the project. An important aspect of this type of organization is the exchange of information that is possible due to the more effective use of personnel [5].

In conclusion, the modeling of the organizational structure of a project can provide information and data which are useful in understanding the social dynamics of the project, interrelationships amongst members of the project, and the correlated functions of the project's members. Without the use of organization models in the A/E/C industry it is quite difficult to know where to send, obtain, or receive certain information and thus makes meeting schedule, cost, and quality demands that much harder [5].

2.3 PROJECT INTEGRATION

In a construction project there are three different categories that all need to come together in order to complete the project: people, product, and process. There are also subcategories of each that needs to be coordinated within itself in order for the project to work. Integration has been defined as, "the process of achieving unity of effort among the various organizational subsystems in the accomplishment of the organizations tasks," [1].

Figure 2-3: What Integration Looks Like

When everything & everyone is working together as one large unit a project is considered to be fully integrated, which would be the ideal solution for everything involved in a project to work together. Certain aspects like project type, project phase, and parties involved, technology used and the contractual arrangements can affect project integration in a project. Over the last few decades a large part of the construction industry's low performance rating in the United Kingdom has been blamed on because of disintegrated and fragmented project teams. Even though getting everything to work just perfectly and everyone to agree on everything does not happen all the time thus there are different levels of integration for each project, phase, category, and subcategory.

One of the first applications of integration is derived from the first factory organizations where Strutt and Arkwright established the first successful factory in the early decades of the nineteenth century and put together both the efforts of work people and productive machines were as an integrated process to increase productivity [5]. The amount that their profits increased along with their revenue and quality demonstrated how effective and valuable an integrated solution is [10].

2.3.1 Mechanisms & Projects which Promote Integration

The type of project, contractual arrangements, organizational structure, and technological capabilities all affect the application of integration to a project. The business environment is a large indicator on whether integration should be a requirement on a project. Thus as the project uncertainty, complexity, and speed increases the degree of integration within that project also increases [1].

Design/Build and fast track projects were found to be the most common type of project that involves and allows for application of integration. Since design/build projects require responsibility from all parties (design, engineering, construction, owner) there exists a high potential for the application of integration. Thus the contractor can participate to the design from the beginning of the project and propose cost effective alternatives and possible improvements in constructability of the project [1].

A factor that can promote integration (especially when incorporated with design/build projects) in a project is certain arrangements that exist within the contract for the project. One of the most common contractual mechanisms which allows for the contractor to be involved in the design is to require Value Engineering as a part of the design process of the project. By having this requirement in the contract the contractor can review, propose, and influence the design and help with cost savings after the contract has already been awarded. This process is effective if the contractor is brought in while the design phase is still in process. If this procedure is done after design is complete it can require changing a completed design, further investment in engineering services, and a possible delay in the project [1].

Another mechanism which promotes integration is the use of organization methods such as partnering and cross functional teams. Using a matrix organizational structure and developing cross functional teams from the early design phases of a project develops strong integration within the project's organization and create a more effective project team. Partnering within a project helps to increase the effectiveness of teamwork of the project and helps to develop better attitudes and interpersonal skills. One of the best benefits of partnering is that it creates an environment of cooperation and trust, which results in higher levels of effectiveness and thus allows for better integration. Most firms achieve these results by using Total Quality Management, a process which enables employees to identify coordination problems [1].

Lastly, technological mechanisms also have a large effect on promoting integration within a project. Using information technology as a way to improve organization integration has been shown to be effective through creating links for all parties of a project. If used all necessary data that all parties of the project often need to refer to or require for their own use is readily available to them and they do not need to wait to receive the data or information they need. Information technology usually helps increase the integration between the various construction functions such as scheduling, estimating, cost control, establishing links between office and site, but these functions are limited to the contractor's organization [1].

2.3.2 Integration in Project Phases

The degree of integration in a project varies on the phase of the project. Different phases require a different level of integration because each phase is different and involves a varied interaction and level of the different parties in a project. Below in shows the traditional roles of project participants in a non-integrated project and shows the roles of project participants in an integrated project.

From previous research it was seen that integration within the Owner's organization was a key issue especially for large corporations. The less integration in this phase amongst all parties can result in unclear priorities and scope, unidentified needs and constraints, which all can result in change orders, delays, and increased cost. Thus during the design phase integration is essential and critical because it helps to prevent problems in subsequent processes and also allows for selection of alternatives that can optimize the overall performance of the project. In order for this to happen, participation from all parties involving the owner, design, and construction teams [1].

During the construction phase of the project the responsiveness of the organization of the project becomes essential. The uncertainty that comes with the physical and business environment of a project requires constant interaction and response in order to make fast and effective corrections if needed to optimize the productivity of the project. In the public sector of construction it has been demonstrated that the construction phase of a project was most important for integration [1].

2.3.3 Benefits

Overall, in a research study published in the Journal of management in engineering in the January/February 2000 issue it was found that managers interviewed on integration agreed that integration was a more effective approach to facility development because it allows for a better definition of scope and cost effectiveness. A better scope definition is achieved through all parties helping to identify constraints and communicating the objectives of the project to all participants. The project is more cost effective because of integration due to the increased ability to develop and choose alternatives which can optimize the performance of the project. The managers interviewed believed that from the integrated approach to project development they achieved a savings of around 10 to 20 percent of the total project cost and time (their estimate of savings was not based on actual data but on their general observations and responses) [1].

2.3.4 Research on Integration

Integration can be identified from identifying the factors that either promote or deter integration. Promotional factors are factors which promote integration whereas deterrent factors are those factors which deter integration. Although there exists certain barriers which can restrict the use of integration of a project such as investment, difficulty in measuring cost versus benefits, lack of standards resulting in the reduced ability to utilize integration across projects, and the lack of organizational culture to support and promote integration.

Moving away from the rigid and split structure of relations will only help drive the continuous improvement towards and excellence in a market driven environment through the progress of integration in the A/E/C industry. In order to analyze and understand what relates and indicates project integration many researches have focused on identifying the strengths, barriers, and critical success factors of various forms of such collaborative working arrangements. Within each part of a project that adds to the total project's integration are certain factors that need to be analyzed to see how they contribute and affect a project's integration. Research conducted by Hong Kong based studies of Rahman and Kumaraswamy has presented interesting evidence of an overall enthusiasm in the industry for producing relationally integrated information and project teams. They produced a study published in the Journal of Construction Engineering and Management in July of 2005. The created a questionnaire that had various sections that focused on factors which facilitated or deterred the building of integrated teams. They used a seven point Likert scale to determine the perceived level of importance of various facilitators and deterrents to integrated teams. The proposed factors were based from a precursor study performed by Rahman and Kumaraswamy in 2002, 2003, and 2004. They had found twenty eight potential facilitators for integration and 31 potential deterrents. These can be seen in Table 2-1: Driving/Deterrent Factors of Integration.

Driving Factors	Lowest Importance = 0			Highest Importance = 6			
Enlightened and enthusiastic client	0	1	2	3	4	5	6
Knowledgeable client (about project processes and RC)	0	1	2	3	4	5	6
Client's initiative	0	1	2	3	4	5	6
Learning about RC approaches before contractings (all parties)	0	1	2	3	4	5	6
Co-operative learning within project organization	0	1	2	3	4	5	6
Familiarity/previous relationships with/among other parties	0	1	2	3	4	5	6
Repuration in the industry (each party)	0	1	2	3	4	5	6
Willingness/enthusiasm of involved parties	0	1	2	3	4	5	6
Previous experience in RC approaches (each party)	0	1	2	3	4	5	6
Adequate resources and technical skills (each party)	0	1	2	3	4	5	6
Previous performance records on hard factors like time, quality, safety (each party)	0	1	2	3	4	5	6
Compatible organization culture of involved parties	0	1	2	3	4	5	6
Interpersonal relations/cultural harmony (individual)	0	1	2	3	4	5	6
Previous performance records on soft factors like joint decision making, provlems, issues, etc (each pa	0	1	2	3	4	5	6
Short listing capable and compatable potential project paartners istead of price only consideration	0	1	2	3	4	5	6
Disclosing project information to potential partners at early stages of project for optional feedback	0	1	2	3	4	5	6
Seeking specific inputs on constructibilit, construction methods, materials fom potential partners	0	1	2	3	4	5	6
Selecting the best possible, capable, and compatible project team from potential partners	0	1	2	3	4	5	6
Bringing contractor, major subs and suppliers into the project team for longer term interactions	0	1	2	3	4	5	6
More workshops for better interactions to build trust/reliability	0	1	2	3	4	5	6
Use of single point responsibilty	0	1	2	3	4	5	6
Group combined responsibility as against individual responsibility	0	1	2	3	4	5	6
Role of an independent full time facilitator in building trust, teamworking and can do spirit	0	1	2	3	4	5	6
Role of Project Manager as facilitator as per item above given that PM has best understanding and co	0	1	2	3	4	5	6
Requirement for an indpendent full time facilitator to supplement PM	0	1	2	3	4	5	6
Company training policy to build adaptable individuals for working with diverse partners (each party)	0	1	2	3	4	5	6
Corporate strategy of building trust with potential partners by doing the righ thing and meeting time &	0	1	2	3	4	5	6
Deterrent Factors	**Lowest importance =0**			**Highest Importance = 6**			
Lack of client's knowledge about projec process and RC	0	1	2	3	4	5	6
Lack of commitment from top management: client	0	1	2	3	4	5	6
Lack of commitment from top management: other party	0	1	2	3	4	5	6
Lack of client's initiatives	0	1	2	3	4	5	6
Bureaucratic client organization	0	1	2	3	4	5	6
Stringent/incompatible public sector rules and regulations	0	1	2	3	4	5	6
Public secotro accountability concerns	0	1	2	3	4	5	6
Price only' selection methods	0	1	2	3	4	5	6
Commercial pressures on contracting parties	0	1	2	3	4	5	6
Oportunistic behaviour of one or more contracting parties	0	1	2	3	4	5	6
Lack of trust and reliability among contracting parties	0	1	2	3	4	5	6
Unwilling and unenthusiastic participation of contracting parties	0	1	2	3	4	5	6
Interpersonal and cultural clash (individual level)	0	1	2	3	4	5	6
Incompatible organzational culture	0	1	2	3	4	5	6
Absence of any risk reward plan	0	1	2	3	4	5	6
Separate and unrelated risk reward plans for different parties	0	1	2	3	4	5	6
Exclusion of consultants in risk reward plan	0	1	2	3	4	5	6
Exclusion of major subcontractors in risk reward plan	0	1	2	3	4	5	6
Exclusion of major suppliers in risk reward plan	0	1	2	3	4	5	6
Unfair risk reward plan	0	1	2	3	4	5	6
Lack or absence of contractural relations between client and major subcontractors	0	1	2	3	4	5	6
Lack of any relationships or communications between client and major suppliers	0	1	2	3	4	5	6
Lack of relationships or communications between subcontractors and suppliers	0	1	2	3	4	5	6
Resistance of contracting parties to integrated project culture\	0	1	2	3	4	5	6
Failure to share information among contracting parties	0	1	2	3	4	5	6
Presistence of master and lave concept	0	1	2	3	4	5	6
Uneven commitment of contracting parties	0	1	2	3	4	5	6
Discontinuation of open and honest communication	0	1	2	3	4	5	6
Improper planning, design erros and omissions	0	1	2	3	4	5	6
Potential legal liabilities in resolving non contractual issues	0	1	2	3	4	5	6

Table 2-1: Driving/Deterrent Factors of Integration [14]

The data they received reflected that 27 out of 28 factors that were identified are likely to facilitate building an integrated based project team to result in a more effective relationship amongst parties. They performed a study which surveyed a sample of 200 contractors of different variation and received a 30% response resulting in 60 responses. A Profile of the Respondent Organization Categories can be seen below in

Table 2-2: Profile of Respondent Organization Categories.

Contractor Category	Tender limit (million Singapore $)	Paid-up capital (million Singapore $)	Number of Respondents
A1	Unlimited	15.0	10
A2	65.0	6.5	14
B1	30.0	3.0	18
B2	10.0	1.0	17
Unknown			1
Total	200		60

Table 2-2: Profile of Respondent Organization Categories

They found that the three most important factors were reputation in the industry of each party, disclosing project information to potential partners at early stages of a project for any optional feedback, and previous performance records on soft factors such as joint decision making, joint problem solving, and compromises on unclear issues in each party. They also found that a better reputation is closely related with a greater trust. On the other side of things the three least important factors were more workshops for better interactions to build trust and reliability, learning about RC approaches before contracting through workshops, seminar or training within the company, and the requirement of an independent full time facilitator to supplement the project manage in building trust, team working and can do spirit and enhancing cooperative learning among contracting parties; thus workshops are of little importance and impact in integration [14].

2.3.5 Factors Indicating Integration

From Rahman and Kumaraswamy's research they identified four different components amongst the factors that indicated integration that explained for the percentage variation amongst the different contractors responses. The four components were: (1) Client's competencies and overall learning and training policy, (2) Previous interactions, performance, competencies, and specific inputs and outputs of various partners, (3) Compatible organization culture, longer term focus and emphasis on trust building, and (4) Improved selection of project partners and better responsibility delegation. The first component consisted of 8 different factors that focused mainly on the client's knowledge of project processes and enhancing the cooperative learning among contracting parties. Component two contained six different factors that focused mainly on the familiarity among the partnering parties and a careful assessment of the competencies and potential special inputs of the contracting parties.

2.3.6 Factors Deterring Integration

They also identified five different components which deter integration amongst parties which were: (1) Lack of trust, open communication and uneven commitment, (2) Commercial pressures, absent or unfair risk-reward plan, incompatible personalities and organization cultures, (3) Lack of general top management commitment and client's knowledge and initiative, (4) Lack of good relationships among the team players, and (5) Exclusion of some team players in risk-reward plan, errors and cultural inertia.

The first component contained five different factors that looked mainly on the lack of trust and reliability among contracting parties, their failure to share information among contracting parties and discontinuation of open and honest communication. The second component contained 9 factors that focused on the emphasis of the risk reward plan and the cultural clash at both the individual and corporate level. The third component consisted of four different factors that focused mainly on the lack of top management commitment and the client's knowledge. The fourth component represents four factors and dealt with the lack of good relationship and communications among the project team which may deter building a project based integrated team for RC. The fifth and last component represented four different factors which emphasized the exclusion of consultants, major subcontractors and major suppliers in any risk-reward plan.

The research here demonstrates that the general appreciation of a need for relational integration in projects is present and that it is often effective. Their results also show and suggest new ways in which to move forward with findings in other contractual fields.

The promotion of utilizing project integration has been determined with previous research [1] to be driven by business environment and the demand for project integration. The Business Environment has factors like increased customer needs, increased competition, and new technology that have developed need within projects to develop better project integration. Such factors as increased uncertainty, increased project complexity, and the need for a reduced budget and schedule have created a greater Demand for Project Integration. Most of these factors are what drive and create incentive for a project to have higher levels of integration. Some general contractors, owners, and architects believe that having better project integration can decrease a project's cost and schedule by at least 10 to 20 percent. With time and money two of constructions largest concerns having better integration with all parts of a project are seen as essential to a project. [1]

Due to the high degree of specialization and differentiation between all aspects of a project a strong need for integration of all parts of a project is needed to obtain the best results. The more disintegration among organization, processes, and product the more difficult it is to organize everything, meet schedule demands, stay within budget, and make decisions, etc. [1]

2.4 VALUE ENGINEERING

Value engineering is a methodical analysis of a project's design as a means to maximize the value of the project for every dollar of cost of the project. Over the past years, value engineering has been primarily used in the industrial sector of business in order to demonstrate how to improve value and quality, but recently there has been an increase in the amount of engineering firms using it. There have even been whole design firms that have devoted themselves to the development and analysis of value engineering on projects. Even some federal agencies that issue contracts for large construction projects are requiring that value engineering be used during the design phase of the project [10].

2.4.1 History

Value Engineering has always been around and utilized in all engineering because every industry considers and weighs the maximum economy and value in the selection and use of their design or product. After World War II cost reduction and industrial cost effectiveness had now become a new concern amongst companies because of material shortages. In 1947 the term "value analysis" was coined at the Lynn, MA plant of General Electric, by Larry Miles, Manager of Value Services at GE. Harry Erlicher had assigned Miles the task of developing plans to obtain a better value on the parts and materials that GE purchased. When there had been no loss in function or reliability with the change of parts and materials even though they were less expensive, Erlicher realized that GE should use an organized approach to reduce its costs [10].

From this Miles started a division of GE which forged a program there saving millions of dollars at the Lynn, MA plant. It only took 12 years before there were over

120 value analysts employed throughout the GE Company and the Society of American Value Engineers was formed in Washington, D.C. Over the years the requirement of value analysis in projects has come to be more accepted and recognized. Massachusetts was one of the first state and municipal governments to require value analysis programs as a means to reduce their operating cost expenses [10].

The concepts and procedures that started from one man and saved GE millions exploded into a new field of engineering that has grown and produces desirable results. Value engineering has spread throughout the world and has provided an organized, systematic, state of the art method to reducing cost and still retaining value [10].

2.4.2 Engineering & Analysis Process

It has been shown that there are a variety of tools available to companies to analyze the value of their product, design, or project in relation to cost and quality, but what is different about value engineering (VE) and analysis from all these other methods is that VE looks and what the product does for the customer not what it is. This process is called function analysis and is the foundation of VE [11].

Even though value engineering can be a lengthy and rigorous task it can improve the value and optimize the life cycle of cost of a facility or project immensely. Over 30 years ago GE was saving $25 for every dollar that they spent on value analysis (Brown, 7). Thus, it is obvious that value engineering is an effective tool in helping management and companies to improve decision making as means to achieve a variety of objectives such as to save money, reduce time, improve quality, reliability, maintainability, and/or performance. It also can be used to improve on attitudes, creativity, and teamwork of people. The process of value engineering is to identify areas where costs can be cut while still maintaining the quality, reliability, performance and other essential factors in order to meet the demands and expectations of the customer, owner, or project. Therefore, the cost constraints are performed without sacrificing performance or time needs [11].

There are three basic fundamentals that demonstrate value to the customer or owner and they are: function, quality and cost. These three factors are related by the following:

$$Value = \frac{Function + Quality}{Cost}$$

Function is defined as the specific work that a design or task must perform. Quality is defined as the owner's, customers', or user's needs, desires and expectations. Cost is defined by the life cycle cost of the product. The relationship between all of these factors is equal to the value of the project, task, or object and is defined as the way which is most cost effective as a means to accomplish a function that meets the quality defined by the owner, user, or customer [11].

Many techniques can be used to achieve the objective of value engineering is to improve value but there are a variety of unnecessary costs that also can arise. These unnecessary costs that can lead to poor value come from lack of information, lack of ideas, temporary circumstances, honest wrong beliefs, habits and attitudes, changes in owner requirements, lack of communication and coordination, and outdated standards and specifications. Each of these reasons provides an area for improvement where the efforts of value engineering can be effective. In a study performed by the US Department of Defense in 1965 showed that the seven most significant factors that were responsible for savings actions were excessive cost, questioning specifications, redesign cost, change in user/s needs, and feedback from user, design deficiencies, and advance in technology [11].

In order for value engineering to be most effective it should be applied as early as possible in a project or task; before the commitment of funds, approvals, services, or designs. The savings from value engineering is extremely higher the earlier it is applied. If applied later the investment needed for changes and the resistance to change both, increase [11].

2.4.3 Economics

The goal of almost every company is to be successful and almost always that is measured by the amount that is earned in profit. In order to achieve this goal the cost and its correlated effects must be thoroughly understood and analyzed. A key tool in understanding what something costs before it is made, used, or applied to an idea, concept, process, or service is to perform target costing. The primary concern of target costing is to determine the cost of a product before it is designed or applied. This tool is quite useful but it is not a universal practice amongst most companies. Target pricing determines cost goals based upon the customer's wants, needs, and company profitability requirements. In order to meet these target cost goals planners and engineers need to be effective in creating creative and flexible ideas by fully understanding the cost and function involved [12].

In order to understand exactly where the costs of a project go for civil engineering projects producing cost estimates as a function of time has been deemed very useful. If there is effective cost estimating then cost reduction programs like value engineering for the project can work effectively. Cost Estimating done at the conceptual and schematic design phase of the project is very important because they can produce final estimates with an accuracy of plus or minus 15%. How the cost of a project approaches the target cost as the project progresses is shown in Dell'Isola on page xxiii. Here it shows the potential savings that can be achieved through the application of Value Engineering. The extent of the amount of savings of a project will vary according to the proportion of the amount of spending and expenditures that were performed. In Dell'Isola page xxxii, he shows the results of value engineering programs with large facility expenditures. By looking at the results as seen in the figures above it can be seen that the earlier value engineering is started in a project the more cost effective it is [11].

A variety of unnecessary costs can lead to identify important points where a value engineering effort could be effective. Having insufficient data on what the owner's or users wants and needs are and lack of knowledge on new materials, new processes, or products that could meet those wants and needs within the target cost range; lacking creativity in determining alternative solutions; illegitimate decision making, change in owner requirements, lack of communication and coordination, and outdated standards and specifications. In order to determine the foundation of opportunity for VE studies in 1965 an initial VE program study was performed by the US Department of Defense. This study gathered information from 415 successful VE studies demonstrating value changes and obtained an indication of range and degree of application of VE studies. The information obtained from the study identified seven factors that provided for 95% of the savings obtained from the VE study that was performed. "The Seven Most Significant Factors Responsible for Savings Actions" can be seen on page xxii in Dell'Isola. The study found that VE action resulted from several factors not just one and did not necessarily correct bad designs but just enhanced most designs and thus providing for an improvement in the value of the product [11].

Thus, understanding the economics of value engineering and the impacts that it can have on a project is a big part in recognizing the value and importance of its use in projects. Developing target costs, sticking to a budget, performing efficient cost estimates, and understanding the mitigating factors of unnecessary costs associated with a project all help further this concept. The graphs that were also provided are an effective guide in providing visual representations of the effects of value engineering.

2.4.4 The Human Factor

Since projects involve a high amount of collaboration required by a large group of people each person plays a role in affecting the cost of a project. The key people in a project often play the greatest role in controlling that aspect of a factor and thus also play a key role in the value engineering analysis of a project. Thus the existence of certain communication skills, motivations, and effective teamwork all play a necessary role in providing an effective journey towards producing a collaborative value engineering analysis of a project.

Different members of the project team have different levels of impact on the cost of a project at various times throughout the project. An owner has more control over the cost of the project at the beginning of a project because he/she is developing and in control of his/her requirements, standards, and criteria for the project. This is similar to when a project is in the latter half and the contractor has more impact than other parties on the project. A demonstration of this concept can be seen in Dell'Isola on page xxiv [11].

The value engineering team for a project is an important part to producing an effective VE analysis. A conventional approach to determining cost versus function is to perform individual analyses by the designer, contractor, owner, user, or engineer. This conventional approach has been shown to be less cost effective, inefficient as a process, and ultimately returns incomplete results. In Dell'Isola, page xxv shows that a way to overcome these issues of the conventional approach is to make a team effort which concentrates on using brainstorming, creativity, and problem solving as a way to overcome the obstacles [11].

Thus assembling an effective team for a value engineering study is obviously important to its overall effectiveness. Including all necessary members which contribute and control the costs, value, and function of the project should be considered team members which usually include but are not limited to a value specialist, owner representative, designers/consultants, construction manager, architects/engineers, cost estimator, and/or building manager. A figure demonstrating the methodology and techniques of value engineering and its important members can be seen in Dell'Isola page xxvi [11].

2.4.5 Other Management System Tools

There has a variety of other Management system tools developed as a means to define problems in order to develop more efficient organization to improve the operations and results of profitability. Some examples of these tools are Management by Objective, Zero Based Budgets, The Kepner-Trego (K-T) System, Taguchi Methods, Quality Function Deployment, Kaizen, Design for Assembly, Total Quality Control (TQC), Failure Mode Analysis, Simultaneous Engineering, Theory of Inventive Problem Solving, and Benchmarking [12].

In the book Value Engineering: A Plan for Invention there is a figure called **Error! Reference source not found.** on pg. 52 that shows a comparison of the effects that each management system tool has on various attributes. The scale reads a 5 for Major effect or excellent application; 4 for above average effect but nor primary application; 3 some effect but not good application; 2 very minor effect; 1 no benefit. Through analyzing the figure it can be seen that certain systems are more useful in certain stages than others. For example the Management by Objectives system is quite applicable in some sense over the entire duration of the project but has very specific requirements at the initial phase of the project. As the figure shows Zero Based Budget is one of the least effective system tools and gives explanation for why it has lost interest as a system tool. These various management systems were developed in the past to complete a certain task or obtain certain information, but because of the complexity of the analysis or the inefficiency of it a variety of these systems have come to be less utilized. By looking at the figure it can be seen that Value Engineering (VE) in row 13 produces a score of 84 which is 34 points above any other score from other system tools. Also looking across the matrix it can be seen that VE is useful in almost every application. Thus due to the high efficiency and applicability of value engineering, it has come to be the most popular and useful form of management system tools [12].

2.4.6 Risk Analysis

Even though there have been other management system tools that have not worked as effectively as value engineering has, risk analysis has been shown to provide additional results when integrated with value engineering. In 1993 a large city port authority had the opportunity to apply VE methodologies along with a formal risk assessment and analysis. There existed a large 30 year old building that was in the process of a massive overhaul of modernization and similar projects in size and budget had extreme cost and schedule overruns and the owner wanted to avoid these issues if at all possible. In order to try and do this the owner required a VE effort along with application of risk analysis for his project. The VE team worked with a risk analyst and produced feedback regarding potential risk areas and determined a wider range for cost considerations. It was obvious that the combination of the two processes was a very powerful and effective tool for projects [11].

In order to perform this type of analysis in addition to the VE methodology a team was developed which would cover risk assessment and analysis. They first performed a VE study on the project along with an initial risk assessment of the project. The results of this study was then presented to other VE teams and phases of the project where risk needed to be considered was broken down into design, administration and contractual issues, construction, and tenant relations and public image. Risks were then broken down within each phase and then the level of severity of risk rating at either medium or high was applied to each risk factor, excluding random or extraordinary risks [11].

3 METHODOLOGY

Figure 3-1: Model of WPI Residence Hall on Dean St [15]

3.1 WPI RESIDENCE HALL CASE STUDY

Worcester Polytechnic Institute (WPI) decided that they wanted to provide more upper-classmen housing in order to draw students back to campus and to accommodate for future growth, and in the summer of 2006 the school hired Cannon Design to start to develop a study for an existing building site on campus. Cannon Design firm out of Boston, MA is a renowned design firm demonstrating proficiency in educational building [see Cannon Design below]. The project is located next to Founders facing Dean St and is going to involve new residence halls and a new parking structure. They wanted to achieve these goals while being environmentally sensitive, respectful of the surrounding Worcester community, and also incorporate the arts walk into the arts section of Worcester. In order to maintain environmentally safe the WPI Residence Hall is going to try and achieve a Silver Ranking from the Leadership in Energy and Environmental Design, a program administered by the US Green Building Council. The WPI Residence Hall project is a fast-track Construction Management Project. This research project has followed the project from the third meeting of the committee on September 20th 2006 until April 20th 2007 with the research focusing mainly on the design phase of the project [15].

3.1.1 Goals of Project

The goals of the new WPI Residence Hall Project as outlined by WPI are:

- Provide upper-class housing to draw students back to campus
- Maximize use of the site
- Relate to and respect the Worcester community
- Design a project that is environmentally sensitive
- Accommodate the Arts walk to the south, adjacent to Founders Hall

[15].

3.1.2 Stages

Throughout the design phase of the WPI Residence Hall Project there were three separate sections that the design process went through until it was essentially completed, which were: conceptual design, schematic design, and design development.

3.1.2.1 Conceptual Design

The conceptual design phase is the first phase of design where drawings are the dominant tool and product. Usually, drawings in this phase are composed of simple, single-line floor plans, building sections, elevations, and site plans. The WPI Residence Hall after two months of investigation and deliberation on different design schemes for the building finally decided on scheme E as the design for the building. This scheme provides 232 beds and a 5 level building facing Boynton Street next to Founders and abutting the Church of Our Savoir. In addition to the building 150 external parking garage structure is also included in the project. The construction estimate performed by both Gilbane and Canon Design indicate that there are $31.5 million in construction costs

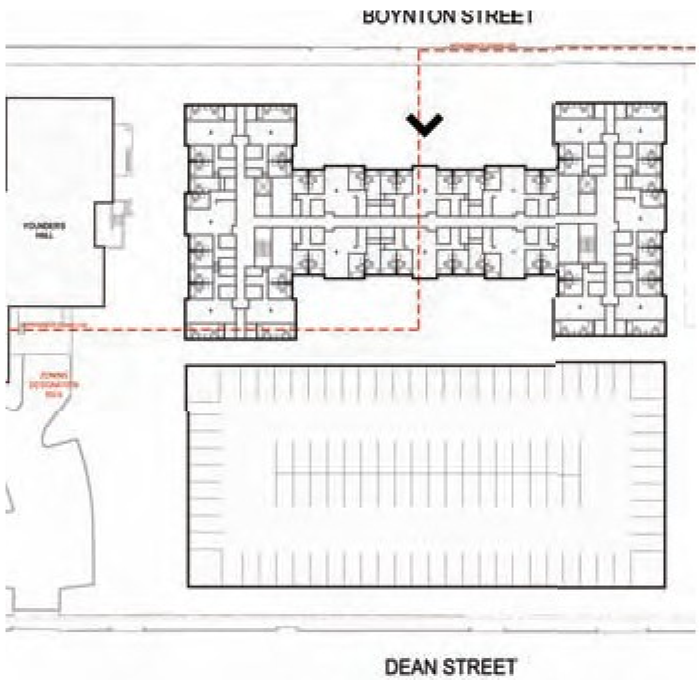


Figure 3-2: Design Scheme E [15]

for the building and $2.5 for the garage and the project is carrying around $4.5 million in contingencies. The conceptual design phase of the New WPI Residence Hall was completed on November 17, 2007.

3.1.2.2 Schematic Design

The schematic design is the second stage of design during the design phase which represents the period where all questions about the project are identified and general concepts are refined in order to represent the ultimate design. Schematic design although is not specifically detailed. Instead it merely just identifies details that require further study. It does however offer the first understandable look at the building and shows the ultimate form and character of the building. The schematic design phase of the New WPI Residence Hall was completed as of January 31, 2007.

Figure 3-3: 3-D Schematic Design Perception [15]

3.1.2.3 Design Development

The design development (DD) stage is the last section in the design phase and is where the design is now at 100%. There may be slight changes here and there provided through change orders as the project moves on but essentially the building's design is complete. The design development report was released on March 31, 2007 and the final documents of design development of the New WPI Residence Hall were released on Friday, April 20, 2007.

Since the WPI New Residence Hall is a fast track project, construction for the project has already started and began before the Design Development stage was complete. The information obtained from the schematic and conceptual design stages provided enough information to allow the project to proceed to construction. Cannon Design met with the WPI Residence Hall Committee bi-weekly to discuss final program requirements, building standards, and finishes in order to confirm the layout, size, and adjacencies of each element, fixture, and finish. Below is a picture of the new WPI Residence Hall from the perspective along the arts walk.

Figure 3-4: Design Development - Perspective along Arts Walk [15]

Each separate design stage of the project has produced different variations of the bed, distribution of beds, and the single to double bed ratio. Below is a matrix which shows the number of units for the building each separated into the different type of units, the number of singles, and the number of doubles for the building. As seen in the schematic

	4-Bedroom (4 single rooms)	4-Bedroom mix (2 singles/1 dbl)	Studio	Totals	Percentage
Number of Units	16	40	8	64	
Number of Singles	64 beds	80 beds	8 beds	**152 beds**	**66%**
Number of Doubles	0	80 beds	0	**80 beds**	**34%**
Total Beds				**232 beds**	**100%**

Figure 3-5: Design Development Bed Count Matrix

design, a matrix below presents a comparison of what the percentage of bed type for the schematic design and then what it is currently along with the square footage per room and for the building. There was no change in the proportion of beds but the GSF/bed was reduced to 446 ft^2 from 447ft^2. A new development that came out of the schematic

	Schematic Design Program	Current/ Actual
Percentage of beds double rooms	30%	30%
Percentage of beds in single rooms	70%	70%
Total Gross Sq. Feet	103,610	103,473
GSF/bed	447	446

Figure 3-6: Design Development Bed Proportion & GSF

design was integrating an option of a green roof into the WPI Residence Hall building. One of the largest reasons for considering this new design option was that there exists little green space at the Boyton/Dean Street area of campus and by adding this design it would create better aesthetics around that area. Also its associated cost did not increase the cost of the project extensively either.

3.1.3 Parties involved

There are three main parties which form the Project Team for the new WPI Residence Hall and consist of Worcester Polytechnic Institute, Cannon Design, and Gilbane Company. An overview, description, and the role of each party are provided below.

3.1.3.1 WPI

Worcester Polytechnic Institute is the owner of the project. There are a variety of members that are involved with the project that represent the different interests and aspects of the WPI community. There are members involved in the project that represent the student body, residential services, financial representative, plant services, students conducting research on the project, and the dean of students. The individuals and their association are explained in detail in an informational model in the investigation and analysis section of this project.

3.1.3.2 Cannon Design

Canon Design is an architecture, engineering, planning, interior design, and project delivery firm headquartered in Boston, MA with other locations at various spots in the US. The firm was established in 1945, has around 700+ employees, and currently grosses $104.2 million dollars in revenue each year. They have performed other projects at other colleges and universities including the John Hancock Student Village at Boston University, buildings at USC, UC-Berkeley, Tufts, University of Maryland, and SUNY Oswego [9]. Cannon Design in the designer for the WPI Residence Hall project and has been working with WPI since the start of the project.

3.1.3.3 Gilbane Construction Co.

Gilbane Construction Company is a well established building company that offers construction services, turnkey services, and facilities management. Gilbane was brought onto the WPI Residence Hall Project as Construction Manager of the project. Gilbane was founded in 1873 by Thomas and William Gilbane as a family run carpentry and general contracting shop out of Providence, Rhode Island. The company is now in its fourth generation of leadership and is still a privately owned and family run business.

The company is pulling in over $3 million dollars in revenue each year and employing over 1800 employees across the country and US territories. They have been involved with building a variety of projects over the company's history from the 1980 Olympic Venues in Lake Placid, NY, the Vietnam War Memorial, and even the President's House at Brown University in Providence. Gilbane has worked with WPI on the construction of its new Administration Building next to the quad which was finished last May [8].

3.2 PROJECT INTEGRATION

A project integration analysis will be performed on the WPI Residence Hall case study as a means to understand how project integration effects a project, how to identify project integration, and ways in which it can be measured.

3.2.1 Investigation & Identification of Project Integration

One of the past effective methods of measuring project integration was demonstrated by Rahman and Kumaraswamy and was utilized in this research project as a way to observe, measure, and analyze project integration. The questionnaire concerning promotional and deterrent factors of project integration will be used to determine which factors are evident in the WPI Residence Hall Project.

3.2.2 Ways to Measure Integration Factors

A statistical analysis of these findings were produced and computed to demonstrate (1) the usage and importance level of each factor of integration of the project (2) the usage and importance level of each category of factors (3) the correlation between the usage and importance levels (4) Determine if there exists any biases amongst the three different parties (5) Determine areas of where to increase integration and (6) Explore ways in which to quantify the level of integration in the project. In addition associated graphs and tables were also produced to help analyze and explain the results of this research's findings.

3.3 A/E/C MODELS

An analysis was conducted on the case study in order to determine if there were any informational models being utilized, what type they were, and then a presentation of the applicable models and the role that they play in the project was provided. Also any other unconventional methods of modeling that have not been mentioned in previous research but are obvious uses of information management will be discussed, analyzed, and the results of the model presented.

3.4 VALUE ENGINEERING

As demonstrated in the background section value engineering is an important part of a project especially during the design phase of a project. The WPI Residence Hall will be analyzed through value engineering and a risk analysis and assessment. Each analysis interacts with one another and stands independently, although the impact they make when performed together versus separately is quite different. Therefore value engineering will be analyzed separately at first and then a combined integrated analysis will be performed amongst the two.

3.4.1 VE Methodology

A general example of how the Value Engineering process will be integrated into the design of the WPI Residence Hall Project is provided can be seen in Dell'Isola on page xxxv. The WPI New Residence Hall project team developed their value engineering study and in addition to their study two were conducted as a capstone design requirement for this project during the design phase of the WPI New Residence Hall. It will follow the process as indicated in.

There are six different phases that the value engineering analysis will go through before it is complete. The first phase is the information phase which consists of keeping record of consultation and documents, producing a cost summary, a general purpose model, a cost/worth model, and then a construction cost summary. The second phase of the analysis is the function phase which will consist of a function analysis and a FAST Diagram. The third phase of the project is the creative phase which includes the process of generating and brainstorming for ideas. The fourth phase is the analysis phase of the study and performs the present worth method of the life cycle cost and a weighted evaluation phase. The fifth phase of the study is the recommendation phase which involves producing the value engineering recommendation, the cost worksheet, and the summary of the potential cost savings. The sixth phase of the study is presentation and implementation of the recommendations from the study and involves producing an outline for team presentation.

There exists various worksheets that aid the process of completing the value engineering study and they will be filled out as the analysis is completed. Upon completion of the value engineering analysis it will be compare the cost and schedule results to the proposed schedule results from the project team.

The WPI Residence Hall Project Team also completed a value engineering analysis. This analysis will be analyzed and compared to the value engineering analysis that is performed in this research and then they will both be compared and contrasted and the results analyzed and then presented.

3.4.2 Risk Assessment & Analysis

In addition to the value engineering assessment risk assessment has been demonstrated to have a large impact on the effectiveness of VE. As indicated in the background some of the key risk factors that apply to design are the level of information in bid documents, design uncertainties, and environmental/asbestos issues. Dell'Isola provides recommendation for an analysis which is shown below:

1 Improve the documentation of the project prior to development of bid documents.
2 Improve detail of any performance specifications and provisions of information to bidders.
3 Provide bidders with more detail and available documents on existing conditions and owner, local authority guidance on life safety, asbestos, and indoor environmental issues.
4 Schedule a technical review by VE team to focus on ability of design to accomplish objectives without significant adverse impact on costs and revenue.

Then based upon the results provide results, conclusions, and recommendations from the findings involving the assessment of the WPI Residence Hall case study. The method that will be used in the analysis identifies the overall risk factors of the design phase of the project and then compares them to schedule and cost overruns.

3.4.3 Hypothesis

The hypothesis of this research is that by completing the value engineering the results will demonstrate how it is a useful management tool to minimize cost and maximize value of a project.

3.5 MATHEMATICAL MODEL RESEARCH

A mathematical research project was performed in conjunction with this project in order to facilitate the mathematical issues related to this research. The mathematical research analyzed the process of the critical path method as a basis to understand the most common and useful way that project scheduling is used. From this a new model was created which took into consideration project integration and the effect that it has on a project through its schedule & cost.

4 INVESTIGATION & ANALYSIS: WPI RESIDENCE HALL

The investigation and analysis portion of this project is performed based off of the methodologies described in the third section of this paper. These methodologies are going to be applied to the New WPI Residence Hall being build here on campus. First a description of what and how information was gathered will be provided and then an analysis of the data will be produced. The three different aspects which will be analyzed in respect to the New WPI Residence Hall are the use of Information Models on the project, a project integration analysis, and a value engineering study on the conceptual and design development stages of the New WPI Residence Hall.

4.1 INFORMATIONAL MODEL ANALYSIS

4.1.1 Project Type & Model

The WPI Residence Hall Project is a based on a Construction Management project delivery system. The owner (WPI) is highly involved with the process and only has enlisted one agent outside of the organization, a civil engineer from Cardinal Construction, as an addition to their project team to monitor construction cost and project production. All parties involved in the project are using Primavera packaged software to produce schedules for the project. The cost estimates for the project produced by Gilbane Building Company and uses Timberline Precision Estimating.

4.1.2 Process Configuration

There exists no generated process models for this project but a process does exist by which the WPI Residence Hall Committee makes decisions about the design of the building and the project in general. The committee meets every Wednesday at 2pm on

WPI's campus center and almost all the meetings are attended by WPI, Cannon Design, and Gilbane Building Co. Decisions which involve the input of all the different parties of the project are usually confronted and worked out here. Responsibility for certain decisions are placed on individuals within each party but the committee as a whole over the period of analysis had demonstrated an integrated and collaborated approach to confronting issues, making decisions, and solving problems.

4.1.3 Product Organization

There exists no direct product models in this project but the project team did use some information technology and created a site on my.wpi.edu for committee members to have access to the documents for the project.

4.1.4 Organizational Structure

WPI is the owner of the project and has contracted Canon Design from Boston, MA as the Architect for the project; the Construction Manager for the Project (selected after a series of meetings between WPI and Canon) is Gilbane. Within WPI there are different parties that act on behalf of WPI and those are WPI Plant Services, Chief Financial Officer, Dean of the School, Dean of Students, a WPI Student, Director of Residential Services, Current Residential Advisor of a WPI Dorm (RA), Head of Academic Technology Services, WPI Academic Participant, and three various project teams from Civil Engineering who are tracking the project. Canon, the Architectural Designer of the project has 10 different representatives the Project Manger, Project Designer, Design Principal, and the Project Planner.

Organization	**Job Title**	**Name of Person**
WPI (Owner)	Chief Financial Officer	Jeffrey F. Solomon
	Dean of Students	Philip Clay
	President	Dennis Berkey
	Vice President of Student Affairs & Campus Life	Janet Richardson
	Associate Director of Physical Plant	Christopher Salter
	Director of Physical Plant	John E. Miller
	Director of Residential Services	Naomi B. Carton
	Director of ATC	Mary Beth Harrity
	Academic ,Professor of Civil Engineering	Guillermo Salazar
	Executive Director of Corporate & Foundation Relations, WPI Development	Denise Rodino
	WPI Student	Heather M. LaHart
	WPI Student	Jennifer Arellano
	WPI Student	Christine Conron
	WPI Student	Ryan Young
	WPI Student	Krystal Parker
	WPI Student	Jonathan Bourque
	WPI Student	Nathalia Arenas
Canon Design (Architect)	Project Manager	Lynn Deninger
	Project Planner	Peter Hourihan
	Project Designer	Antoni Borgese
	Design Principal	John Berchert
	Project Principal	Bob Peterson
	Planning Principal	Peter Hourihan
	Engineer Principal	John Swift
	Plumbing & Fire Protection Engineer	Ron Furbish
	Electrical Engineer	Brian Pineau
	Mechanical Engineer	Fletcher Clarcq
Gilbane Co. (Construction Manager)	Project Executive	Bill Kearney
	Project Manager	Neil Benner
Brown Sardina (Landscape Architect)	Design Principal	Bill Brown
Cullinan Engineering Owner's Agent	Vice President, Chief Engineer	Ken Hodgson

Table 4-1: WPI Residence Hall Organizational Breakdown

Understanding the organizational structure of the project is important because relaying and sending information about the project to where it needs to go relies on knowing who to talk to and who to send information to.

4.2 INTEGRATION ANALYSIS

An integration analysis was conducted on the New WPI Residence Hall through by attending project meetings and through an integration factor questionnaire. The data that was collected by these means was then analyzed. The following paragraphs provide a description of how the data was collected and an analysis of integration as it relates to the New WPI Residence Hall.

4.2.1 Data Collection

In order to facilitate an integration analysis, data and information from the WPI Residence Hall project needed to be collected. The data for the analysis was collected through attending meetings and distributing a questionnaire ranking the usage and importance levels of promotional and deterrent factors of integration. First a description of selected meetings will be provided along with the correlating meeting minutes that were written for the specific meetings and then a description of the questionnaire will be provided.

4.2.1.1 Meeting #1 Description

Meeting #2 on September 6, 2006 was canceled due to an illness of the head architect. Thus the next meeting (Meeting #3) was scheduled for September 20, 2006. The agenda for the meeting was to review prioritized program goals, review of the building program, design explorations, and miscellaneous issues such as the Construction Manager selections, schedule, and the strategy for review with the building inspector.

The beginning of the meeting started with the WPI Residence Hall Committee Architects and WPI Committee members talking with the Founders Cafeteria Manager and their Architect for the new Pub/Restaurant in Founders. They wanted to make sure that any of the improvements or changes that they were making in Founders how it could affect the new residence hall and if there are anything that they need to take into consideration when renovating. The WPI Residence Hall Committee talked with the Founders Renovation team and tried to figure out how the building will face in order to gear the Pub/Restaurant to coordinate well with the new Residence Hall. One of the main topics of discussion was the 4 ½ foot grade change from the building floor to ground elevation and how this may be encompassed to work well with the new Residence Hall. Another topic of discussion was a Courtyard area that would be developed between the new WPI Residence Hall and Founders. It was noted by both parties that this was an important factor to consider when building but that there was lots of flexibility for creating this space. After talking for 15 minutes it was concluded that the Founders project was to continue as planned and that everything looks good and that it will work with the new Residence Hall.

The Founders Project Team left the room and the meeting moved onto the focus of the meeting, the new WPI Residence Hall. The Project Manager from Canon started off the meeting with discussing the agenda for the meeting and what the key issues for discussion were. The first subject that was addressed was the selection of a Construction Manager (CM); Canon said that they will be interviewing three potential candidates (Gilbane, Walsh, & Bar & Bar) and by Monday they should have a contract to show WPI. The next topic discussed was the problem that WPI was having acquiring the

Police Station Property (as this property is currently not owned by WPI but needs to be acquired in order for the construction for the Residence Hall to begin because the building will lie on that property once it is built). Everyone agreed that it was a work in progress and the project and schedule will continue on as if it has already been acquired.

The Project Manager for Canon gave positive feedback to WPI about the goals that they gave Canon and they believed that they addressed everything and met all their requirements for the project and welcomed any further comments or feedback that they had.

Moving on the Project Manger for Canon brought up the discussion of the Building Review Program: where will the Police Station be relocated and what is the amount of space and requirements that the Police Station requires. The Project Manager next spoke about the way that the information of the project will be available to all electronically. The WPI ATC said that it will exchange names so that the Project Manager can have access to add and change things on the my.wpi site.

The next main topic on the agenda was the Development of the Plans. One of the main concerns is the height of the building and the requirements that the City of Worcester may have for the building and how their authority on the project will affect the design. It was said by WPI that the requirements for the building will not be anticipated as a major obstacle.

The Design Principle and Project Designer for Canon then put drawings up and went over the design of the building with the committee addressing parking, building orientation, design of building in respect to levels, the location of the WPI Police Station and whether to use an elevated courtyard. It was noted that the location for the WPI

Police Station was in a good area but there was flexibility where it could be moved to. The WPI Chief Financial Officer (CFO) stated that the setback for the building was only 10 feet back from the property line and that the City of Worcester might not like that too much, and Canon responded that it maximizes the amount of building space and if it were to be moved farther inwards from the property line it would take away from available space in the potential courtyard between Founders and the new Residence Hall.

Although probably one of the largest design considerations was brought up by WPI Plant Services was snow removal. Some of the designs that Canon presented showed considerable difficulties with snow removal for the parking garage. Certain designs showed better prospect on this issue.

Canon and WPI interacted back and forth considering the different designs orientations that could be used interchanging the levels, the way the building would face, and the various designs for the parking garage. It was noted that depending on how the building was oriented it would affect different issues and requirements of the project such as the height, length, access, Campus Police location, and zoning variance.

One of the key issues in construction was brought up to WPI by Canon, cost. Janet talked about how she met with the President and he said spend what you need to spend because the students want parking and they want a new residence hall. A number was not discussed at this time but was said that it would be provided in the near future. One of the reasons that cost was brought up by Canon designers was because they wanted to consider the possibility of a courtyard option on top of the parking garage and noted that it would be considerably more costly, estimated around $1.5 million. WPI said to keep it open as an option but had not given a definite yes to the idea.

WPI next noted that they wanted to get the CM involved as soon as possible to start working with them to get costs for the project estimated and start engaging with the CM so that structural systems and issues can be taken into consideration. WPI said that it was estimating the cost of the project, Canon noted that they have an in-house estimator and that they would possibly hire an outside estimator also, and it was also noted that the students tracking this project and performing research would also be completing estimates along with the CM once on the project, so there would be anywhere from 4-6 estimates for the project. The Project Manager addressed the committee and told them that aerial photos for the project were complete and the survey of the area was also complete.

WPI Plant Services brought up another consideration of the dumpster location, activity at that area, the service entrance and how the location of all these should be taken into consideration when determining the orientation of the building.

After the meeting had been going on for two hours the meeting came to a conclusion with WPI saying to Canon to develop a more Architecturally Developed Scheme. It was noted that the project is still on a fast track schedule and that the meetings are still on a 2 week schedule. The last minutes of the meeting Canon and WPI were interacting saying that they both understand one another and that there is quite a lot of room for flexibility within the project and it looks like things are progressing quite well with the project.

4.2.1.2 Meeting #2 Description

The meeting started out with Canon Project Manager opening the meeting talking about the previous building design schemes that were looked at. He also mentioned that they (meaning Canon) met with President Berkey and presented to him the various different design options they had for the residence hall. President Berkey had certain recommendations that he wanted the design to have:

- 4 – 5 stories max
- More green space surrounding the building
- All parking to be hid underground
- Relocated Police station to another location
- Be more respectful to our neighbors; be more courteous to the appearance of the building on Dean St.
- Look at providing double beds (about 30%)
- The travel distance to the elevator needed to be reduced. 200 ft was too far for student to travel to the elevator.
- The amount of cars in the parking lot needed to be reduced from 200 cars to 150

A cost was also mentioned amongst the Gilbane, who is the Construction Manager, the CFO for WPI, and the Canon Project Manager, and was said to be estimated at about $265-$285/square foot (including just the construction costs).

After talking for a half hour about the meeting Canon had with President Berkey, Canon representatives preceded to tell us that the new design they came up with in the past 30 hours since they had with the president hopefully will meet the majority of recommendations he provided for the design of the building.

There were five different new building schemes that were presented. There was constant interaction between Cannon and WPI affiliates about choosing the right scheme based off of the new recommendations from President Berkey. It had been determined that having a garage underground could cost around $50,000 a parking space compared to $15,000 a parking space for an above ground two story parking garage. At this point cost has become the limiting factor to the type of scheme that will ultimately be chosen.

The Canon Project Manager moved on to say that because of the design delay and no decision yet, the conceptual design is about a week behind, but the point of conclusion with the design submitted and estimated should be completed in two weeks from the date of the meeting (subsequent to Canon's meeting with the President).

ATC services said that they could provide a computer and project for the project presentation if it was easier or more convenient for them. Canon took the advice but did not seem extremely excited about it; they seemed almost timid to accept the idea of presenting their material in a different way than on paper.

Moving back to the building design scheme, Philip (Dean of Undergrad Students) said that Option A and Option E seemed to be the best, but ultimately Option E was the best. At this point the question of when the City preliminary review would occur, which was determined to be within 2 weeks? The school is still trying to acquire the Police Station.

4.2.1.3 Questionnaire on Integration Factors

As mentioned in the methodology section of the paper a questionnaire was distributed to all parties involved on the WPI Residence Hall Committee. This questionnaire asked the sample to conjecture his/her personal opinion on the usage level and importance level of identified driving and deterrent factors of integration. The specific questions have been removed from the chart and just referred to by the corresponding number. For a reference to the questions please refer to Appendix. The samples were recorded individually and then organized according to their associated group of Designer, Construction Manager, or Owner.

4.2.2 Analysis of Data

To complete the integration analysis of the WPI Residence Hall different concepts involving the data collected from meetings and the factor questionnaire were analyzed. The data that was collected from the questionnaire distributed to the WPI Residence Hall Committee was analyzed according to define and investigate certain concepts as they related to factors of integration. 50% of the questionnaires (six out of the twelve questionnaires handed out) were returned. Out of the six questionnaires that were returned only three samples had marked some deterrent factors but all six samples did respond to the driving integration factor section. Three members from the WPI committee, two from the construction manager Gilbane, and one from the designer Cannon Design returned the questionnaires. The results from the driving factor questionnaire are provided in the following paragraphs.

From the answers received from the questionnaire handed out to the WPI Residence Hall Committee an analysis on of the questionnaire was performed in order to understand the Usage and importance level of each factor of integration of the project. The results from the questionnaire are provided in the appendix of this paper (see chapter 8). A graph that shows the average of each driving factor's usage level versus the average importance level is shown below in **Error! Reference source not found.**. This is an important graph to look at because it provides an easy comparison of the usage levels compared to the importance levels ranked by the samples. The driving factors range from 1 to 31 because there are 31 different driving factors of integration. The usage levels of each factor (seen in yellow as they are in the questionnaire) of the graph are ranked on a scale from 1 to 5 (y-axis) where 1 indicates a very strong usage level of that factor and 5 indicates no usage level of the factor.

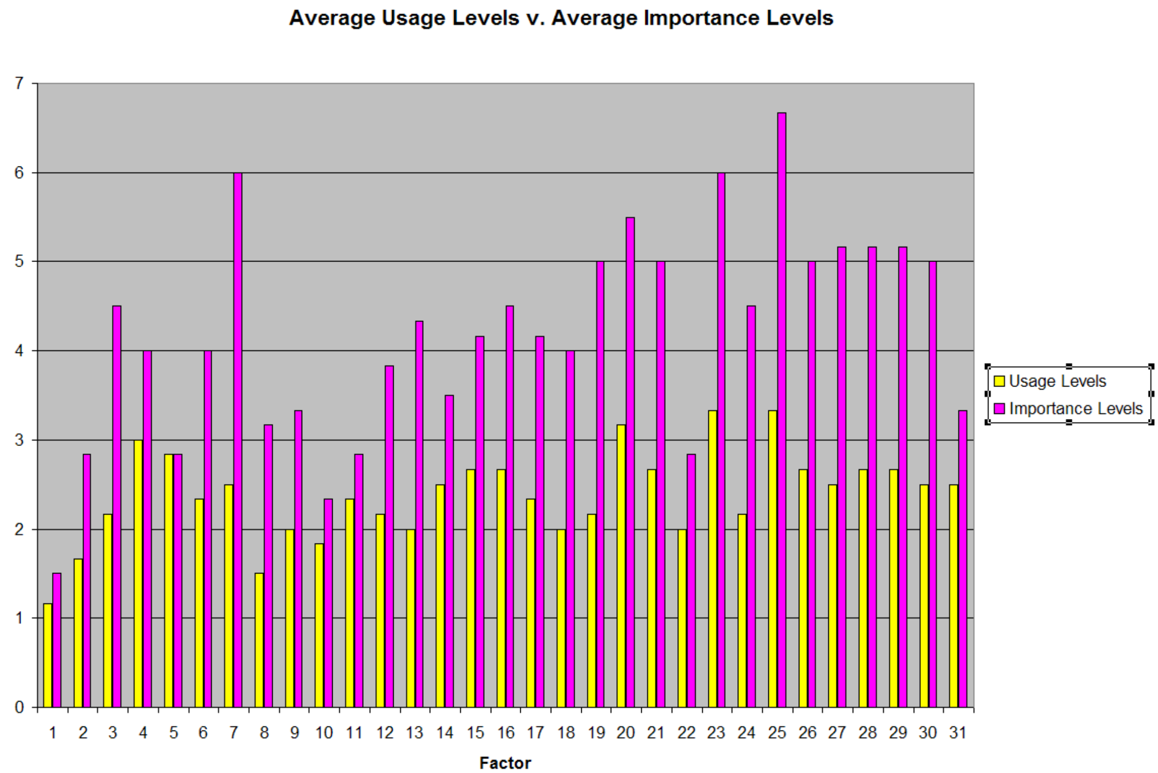


Figure 4-1

The corresponding importance levels of each factor are shown in hot pink (as they are in the questionnaire) and are ranked (y-axis) from 1 to 10 where 1 indicates the highest importance and 10 indicates the least importance of the factor to project integration. What can be taken from these results is the level of usage and importance of the different factors of integration as indicated by the samples. The closer that the average usage and importance levels are to 1 then the more they are being used and the more importance they hold and vice versa for least usage and importance. The top factors which had the lowest mean were

4.1 1.1677, factor #1, "enlightened and enthusiastic client."

4.2 1.5, factor #8, "willingness/enthusiasm of involved parties."

4.3 1.667, factor #2, "knowledgeable client about project processes & integration."

4.4 1.833, factor #10, "adequate resources and technical skills."

The top factors which has the lowest importance levels were

(1) 1.5, factor #1, "enlightened and enthusiastic client."

(2) 2.3333, factor #10, "adequate resources and technical skills."

(3) 2.8333, factor #2, "knowledgeable client about project processes & integration."

2.8333, factor #5 "cooperative learning with project organization"

2.8333, factor 11 "previous performance records on hard factors like time, quality, and safety."

2.8333, factor #22, "group combined responsibility instead of individual."

What is interesting about looking at the top factors that rank amongst the most used and most important of the project is that there exist three factors which are common between the two variables. In order to determine if there is any correlation between the two variables a further analysis needed to be considered, which was a Pearson Correlation.

In order to determine if a correlation between the usage and importance levels existed a Pearson Correlation was performed and then the graph and results were analyzed. A Pearson Correlation is a measure of correlation between two variables of measure on one object and determines if the two variables have a tendency to decrease or increase with one another. The correlation ranges from -1 to 1, and an answer of 1 means that a linear equation describes the relationship perfectly with all the data points lying on the same line and as variable 1 increases variable 2 increases and vice versa. A value of 0 indicates that there exists no linear relationship amongst the variables and they are not correlated with one another. The linear equation which represents this relationship can be generated from linear regression, and this equation can be used to best predict the value of one measurement through the knowledge of the other. The answer provided by the r value (the Pearson correlation coefficient) is the ratio of explained variation to total variation, and is provided by the following equation:

$$r = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-x)^2 \sum (y-\bar{y})^2}}$$

Equation 4-1: Correlation Coefficient

The variables x and y are the sample means and x bar and y bar are the sample variable entries. By squaring r the coefficient of determination can be determined which demonstrates the proportion of variability in a data set. Thus $R^2 = 1$ means that the fitted model explains all variability in y where as $R^2 = 0$ means that there is no explanation available through a linear model.

From the information obtained through the questionnaire a correlation between the usage levels and importance levels of the integration driving factors can be derived. The Pearson correlation (correlation coefficient), line of regression, and coefficient of determination were useful tools which helped to explain whether the two variables were correlated or not. The correlation coefficient calculated was determined to be 0.7678, which means that there is a 76.78% correlation that as x increases or decreases y will also increase or decrease along with it or vice versa. The graph that demonstrates the regression line of the correlation between usage and importance levels is seen below in Figure 4-2. The coefficient of determination was evaluated to be 0.5896. If the two axes were switched the variation would not change even though the equation of the line would.

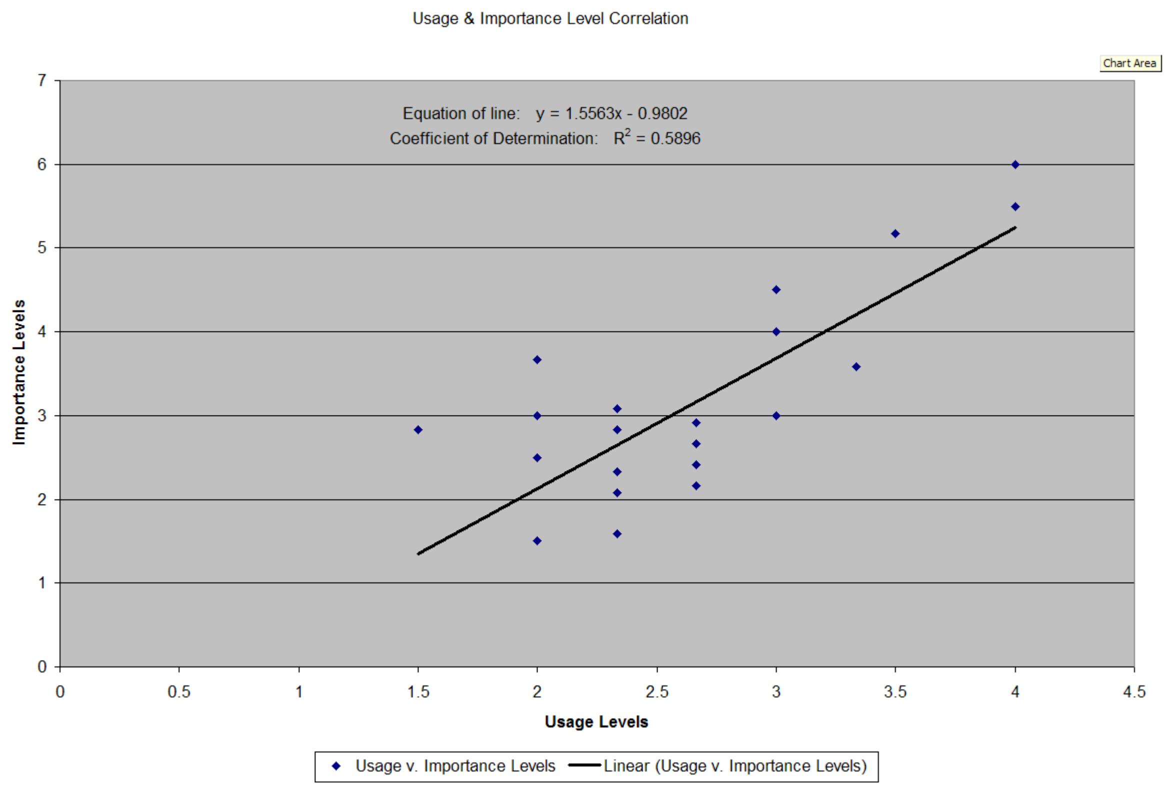
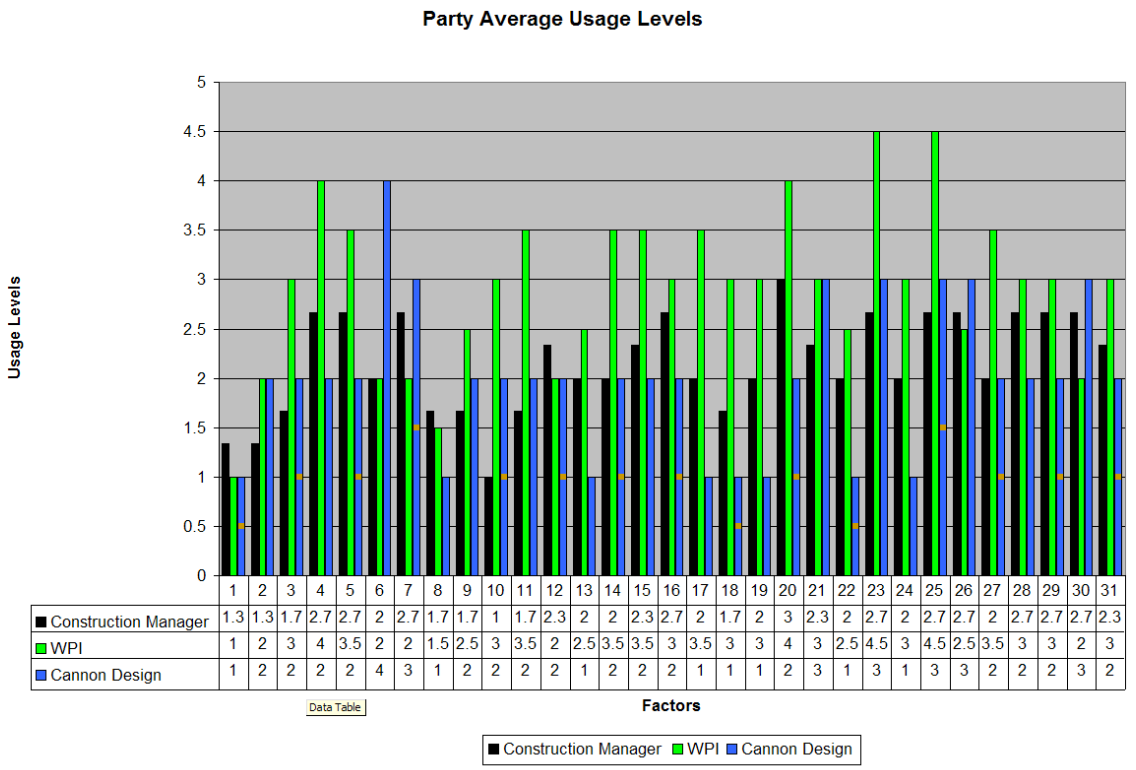


Figure 4-2

The optimal use of project integration would be to have all driving factors of integration being used very strongly and of the highest importance in a project. Not every party in a project holds the same opinion in relation to these concepts. In the sample population there were three different parties which the samples could be categorized according to. Because each party has a different role and perspective of the project there exists a possibility that there could be certain biases amongst the parties, so to determine if or where biases may exist the different parties of the sample were grouped according to their whether they worked as an agent of the owner, designer, or construction manager. A graph which shows the different levels indicated by each group is shown below in **Error! Reference source not found.**.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Construction Manager	1.3	1.3	1.7	2.7	2.7	2	2.7	1.7	1.7	1	1.7	2.3	2	2	2.3	2.7	2	1.7	2	3	2.3	2	2.7	2	2.7	2.7	2	2.7	2.7	2.7	2.3
WPI	1	2	3	4	3.5	2	2	1.5	2.5	3	3.5	2	2.5	3.5	3.5	3	3.5	3	3	4	3	2.5	4.5	3	4.5	2.5	3.5	3	3	2	3
Cannon Design	1	2	2	2	2	4	3	1	2	2	2	2	1	2	2	2	1	1	1	2	3	1	3	1	3	3	2	2	2	3	2

Figure 4-3

It can be seen that WPI ranks usage levels for certain factors slightly lower than both Cannon and Gilbane. In order to see if there exists any correlation between the usage levels as indicated by the different sample groups of Cannon and Gilbane a Pearson correlation was used. The results provided that the coefficient of correlation for Cannon and Gilbane it was only 0.4295, for Gilbane and WPI it was 0.4127, and for WPI and Cannon it was 0.2280.

As project integration has been described to have lasting positive effects on projects it is important to maximize the capability and areas where driving factors of integration can flourish and deterrent factors of integration can be removed. In order to determine areas of where integration in the project could be increased the usage levels of the factors were compared with their corresponding importance levels. If there exists a factor which is ranked of high importance but has low usage levels, by increasing the usage levels of the facilitating factor it is possible that the level of integration of the project could be increased.

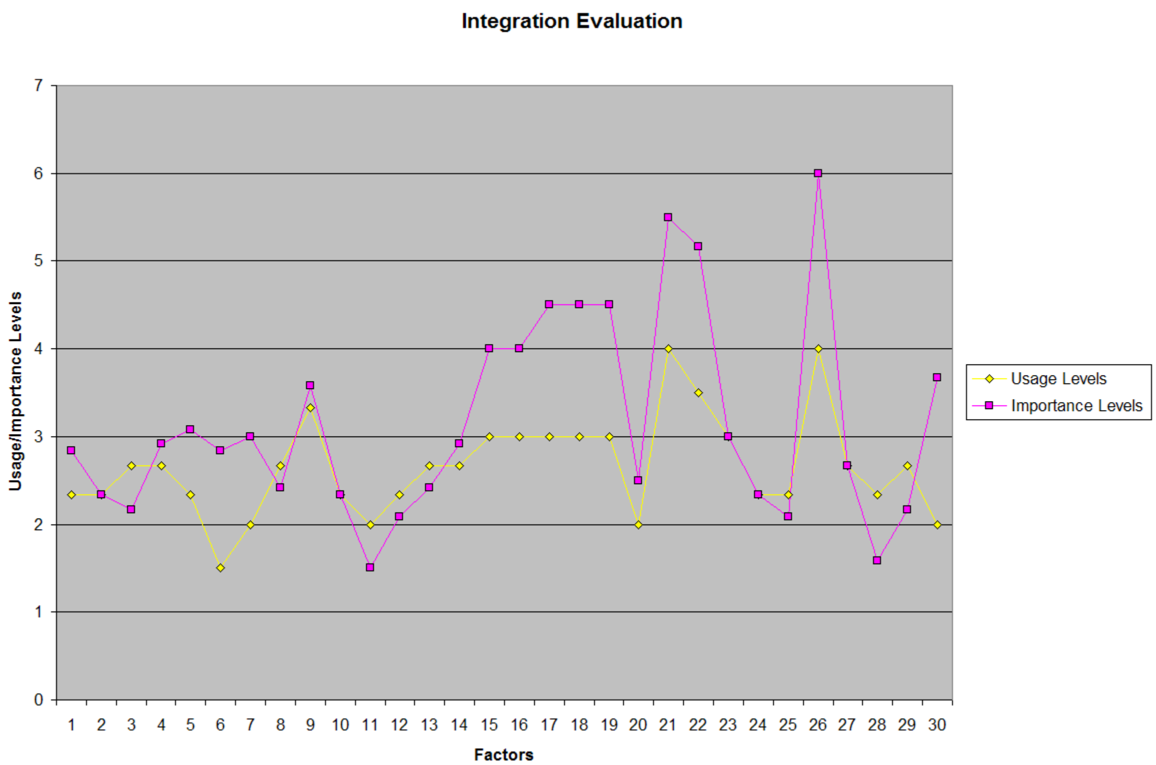


Figure 4-4: Driving Factor Importance & Usage Level Integration Evaluation

There exist eight areas on the graph which indicate that the importance level is closer to 1 than the usage level. These points occur at factors 3, 8, 11, 12, 13, 25, 28, and 29. Since the sample population as an average determined that these areas had higher importance than the level of their corresponding usage they are then indicators of areas where usage levels of driving factors of integration could be increased. If the usage level of driving factors of integration increased then the project integration overall will also increase. For the deterrent factors, only half of the sample population answered in response to them. The closer the usage levels are to 5 and the closer the importance levels are to 10 then the

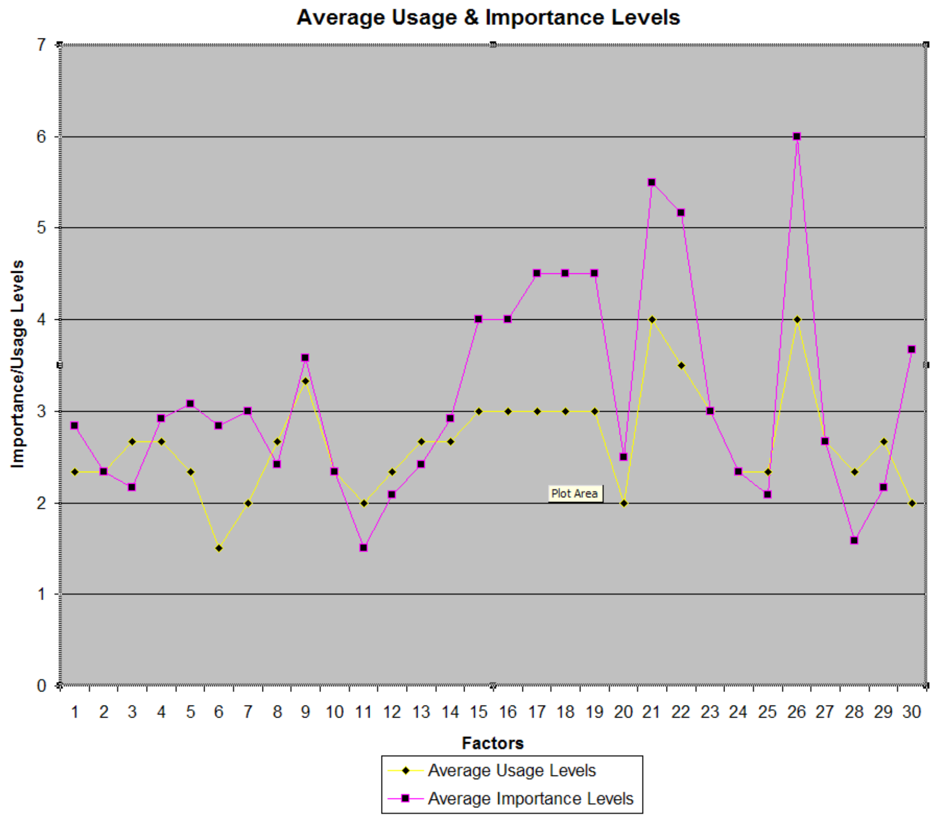


Figure 4-5: Deterrent Factor Importance & Usage Level Integration Evaluation

less likely that the deterrent factors indicated in the questionnaire are adding to deterring integration within the project. For driving factors of integration recognizing the high ranking of importance levels was the goal whereas for deterrent factors of integration recognizing the high ranking of usage levels is the primary analysis goal. By looking at the high ranked usage levels of deterrent factors it demonstrates which factors are deterring integration with project and thus need greater importance placed upon them in order to reduce their high ranked levels. The graph indicates that factor 6, factor 20, and factor 30 both have usage levels that are relatively than their corresponding importance levels.

Lastly, an analysis was made on how to measure the level of integration in a project based on the data from the questionnaires. The average usage levels and importance levels have shown to be useful in demonstrating the average opinions of driving and deterrent factor levels throughout the sample population. From this it was conjectured that using the averages of the usage levels and importance levels of both the driving and deterrent factors would be adamant in determining levels of integration for a project. From the data that was collected from the WPI Residence Hall Committee it was possible to determine the level of integration as pertaining to indicating factors of integration by the method just explained.

In order to understand how the Total Project Integration Level (TPIL) is determined the methodology behind it will be described. First the number of promotional and deterrent factors was determined then a sum of the promotional and deterrent factor levels for both usage and importance of factors were calculated. From this the average was computed which provides the overall promotional and deterrent factor rating. TPIL for the project was calculated by taking the proportion of the driving and deterrent overall factor ratings. There are two different ratings for the TPIL, one in terms of factor usage levels and another in terms of factor importance levels.

An optimum usage TPIL would be 5 and an optimum importance TPIL would be 10. The reasoning behind why a value of 5 would be an optimal usage TPIL is because the optimal usage level average for driving integration factors is 1 (very strong) and the optimal usage level average for deterrent integration factors is 5 (not used at all), and the proportion of 5 to 1 results in a value of 5. The worst case TPIL would be where the driving usage levels would be 5 indicating no usage and the deterrent usage levels would be at a level of 1 indicating very strong usage resulting in a TPIL of 0.2. Therefore the usage TPIL can range anywhere from 0.2 to 5.0 where the lower it is the less usage of integration there is in the project.

The same concept that applied for usage TPIL applies for the importance TPIL. The only difference is that the scale for importance levels is based on a 10 point Likert scale so the proportion and ranges of the overall TPIL are broader. The optimum case for an importance TPIL is a 10 and the worst case scenario would produce a value of 0.1. For the WPI Residence Hall, based on the data obtained from the questionnaire a usage TPIL and importance TPIL were conducted. Below is a summary of the TPIL determination and results. The usage TPIL for the WPI Residence Hall is 1.08 where the importance TPIL for the WPI Residence Hall is 0.73.

	Usage Levels	Importance Levels
Number of Applicable Driving Factors	30	30
Sum of Driving Factor Levels	74	130.1666667
Overall Driving Factor Rating	2.47	4.34
Number of Applicable Detterent Factors	30	30
Sum of Deterrent Factor Levels	79.66666667	94.58333333
Overall Deterrent Factor Rating	2.655555556	3.152777778
Total Project Integration Level	1.08	0.73

Figure 4-6: Integration Analysis Overview

4.3 VALUE ENGINEERING ANALYSIS

As it has been stated value engineering has shown to be an effective tool throughout a variety of fields especially construction. The WPI Residence Hall Committee performed a value engineering analysis after the schematic design phase of the project. This research will first perform a value engineering study which the committee did not perform based on the conceptual design results, then document the WPI Residence Hall Committee's study after the schematic design, and then perform a second study which was not conducted by the committee after the design development stage. The Conceptual Design for the WPI Residence Hall Project was completed on November 17, 2006; the Schematic Design phase for the WPI Residence Hall was January 31, 2007; the completion of the Design Development stage for the WPI Residence Hall was April 20, 2007. Information for the two value engineering studies will be taken from documentation following the completion dates for the design phases.

4.3.1 Conceptual Design Value Engineering Analysis

The focus of the value engineering study during the conceptual design phase will be focused on design concepts, program interpretation, site/facility massing, access and circulation, project budget, design intentions, and net to gross ratios. The goals of this value engineering analysis are to show a 5% savings of initial cost and an additional 5% savings (present worth) of follow-on Life Cycle Costs. The estimate produced in the conceptual design summary report by Cannon totaled initial project costs at $31,530,000 and we are looking to produce a 5% savings.

Savings Goal = **5% of initial cost**
5% of additional costs (LCC present worth)

In the conceptual design report there was a noted increase and change to the amount and percentage of singles to doubles. In the original base program there was suppose to be 30% of single bed private rooms and 70 % single beds in double rooms. In the actual conceptual design review that was changed to 34% and 66% respectively, this resulted in an actual gross square footage (GSF) per bed to be changed to 453 feet increasing the GSF for the building to go from 103300 to 105100. The original cost target for the project was $260 to $285 per square foot, but since the project will be providing apartment style housing the cost per square foot needed to be increased to

$300. Also instead of the standard 330 square feet per bed in traditional dormitory style housing the new WPI Residence Hall will be providing 450 square feet per beds for students. These changes resulted in higher costs for the building. Traditional Dormitory (330 SF per bed) at $260-$ 285 at 232 beds would range from $19,905,600 to $21,819,600. With the advent of apartment style housing the costs increase (450 SF per bed) to $300 per square foot at 232 beds which outputs $31,320,000.00 which is increasingly higher.

The Value Engineering Study goes through a process of collecting information, performing a function analysis, determining cost/worth rations, analyzing ideas, and then determining the cost changes and savings. In order to perform the value engineering analysis information needs to be collected on the project. So answering some questions will provide information.

Questions	Answer
What is it?	Apartment Style Student Housing
What does it do?	Provide Upper-classmen housing On-Campus
What must it do?	Attract Upper classmen back to Campus Increase Number of Beds on Campus Interact with Other WPI Buildings Provide Spaces that Accommodate Today's Student's Needs
What does it cost?	$265 - $300 per square foot
What is the Budget?	Not Provided
What is it Worth	To Be Determined.

Table 4-2: Value Engineering Questions

Let's look at some different alternatives that could help reach the goal of providing a 5% savings. There were three alternatives that were looked at in order to achieve this goal.

4.3.1.1 Alternative #1

The first alternative offered in the conceptual design value engineering study is to look at reducing the cost per bed from $300 per bed to $280 per bed. By doing this the initial project costs are reduces from $31,528,000 to $29,426,880 that results in a savings 6.67% which is $2,101,920. The initial costs are reduced about 7% and the cost per square footage is reduced by $20. The value and quality for the building can still remain the same except for alternative solutions for certain aspects of the project need to be reevaluated in order to create a reduction in cost of around 7%. These values are tabulated in Table 4-3: Alternative Solution Savings Table.

4.3.1.2 Alternative #2

The second alternative that is offered in the conceptual design value engineering study is to look at reducing the bed square footage. If the bed square footage is reduced by a little over 3% which amounts to about 438 square feet but the cost per bed remains at $300 per bed a savings of 3.31 percent is produced, which is around $1,044,000 savings. This is not relatively close to the VE savings goal of 10% total. These values can be seen below in Table 4-3: Alternative Solution Savings Table.

Conceptual Design Alternative Savings Comparison								
	Beds	Per Bed GSF	Cost Per Bed	Building GSF	Construction Cost	Savings	Savings %	CHANGE
Conceptual Design	232	453	$300	105096	$31,528,800	None	None	None
VE Alternative #1	232	453	$290	105096	$30,477,840	$1,050,960	3%	$20/Bed Less, Same GSF
VE Alternative #2	232	435	$300	100920	$30,276,000	$1,252,800	4%	3% Less SF/Bed, Same Cost/Bed
VE Alternative #3	232	436	$280	101152	$28,322,560	$3,206,240	10%	$20/Bed Less, 3% Less SF/Bed

Table 4-3: Alternative Solution Savings Table

4.3.1.3 Alternative #3

The third alternative offered in the conceptual design value engineering study is to taking a combination between the first and second alternative. So the square footage per bed is reduced from 453 SF to 438 SF and the cost/bed is reduced $20 from $300 to $280. With this option a 9.76% savings is produced which is close to the goal of 10%. This can be seen below in **Error! Reference source not found.**. In order to understand the life cycle costs of the building at the conceptual design stage a Life Cycle Cost analysis is performed to provide the present worth the building. This analysis was performed in Microsoft Excel and can be seen below.

Conceptual Design Present Worth Study		
Building SF	105100	
Cost of Maintenance, operations, etc.	$6.25	per ft^2
Interest Rate	12%	7.47
Compound Interest	0.134	
Initial Costs	$31,530,000	48.47%
Annual Costs	$4,906,856	7.54%
Financing Costs		
Initial Costs	$19,784,444.40	30.41%
Annual Costs	$588,822.75	0.91%
Other Costs		
Design	$3,290,000	5.06%
Indirect	$3,425,515	5.27%
Alteration and Replacement	$1,522,899	2%
Total Present Worth & Cost of Ownership	$65,048,537	100.00%

Table 4-4: Conceptual Design LCC & Present Worth

From this it can be seen that the present worth and cost of ownership for the New WPI Residence Hall is around $65,046,537. Now if we consider the different alternatives and compute the present worth of each of them we can see how the small changes as directed by the alternatives affect the present worth of the building. It can be seen that even by the small change not only is there a 6.67% savings in the initial cost of the building but also a 5% savings over the LCC of the base Present worth ($3,422,785) since the LCC is now $61,625,752.

Conceptual Design Present Worth Study	
VE Alternative #1	
Building SF	105100
Cost of Maintenance, operations, etc.	$6.25
Interest Rate	12%
Compound Interest	0.134
Initial Costs	$29,426,880
Annual Costs	$4,906,856
Financing Costs	
Initial Costs	$18,464,778.66
Annual Costs	$588,822.75
Other Costs	
Design	$3,290,000
Indirect	$3,425,515
Alteration and Replacement	$1,522,899
Total Present Worth & Cost of Ownership	$61,625,752

Table 4-5: Alternative #1 LCC & Present Worth

The same worksheet was used for Alternative #2 and it produced only a 2.5% savings over the LCC cost of the base Present Wroth($1,701,042) giving a present worth and total cost of ownership of $63,347,495 as seen in Table 4-6: Alternative #2 LCC & Present Worth.

Conceptual Design Present Worth Study	
VE Alternative #2	
Building SF	105100
Cost of Maintenance, operations, etc.	$6.25
Interest Rate	12%
Compound Interest	0.134
Initial Costs	$30,484,800
Annual Costs	$4,906,856
Financing Costs	
Initial Costs	$19,128,602.30
Annual Costs	$588,822.75
Other Costs	
Design	$3,290,000
Indirect	$3,425,515
Alteration and Replacement	$1,522,899
Total Present Worth & Cost of Ownership	$63,347,495

Table 4-6: Alternative #2 LCC & Present Worth

The final and third alternative provided the most savings for the project and as it can be seen it also produced the most savings in life cycle costs, 8%, and a savings of $5,171,261 over the base LCC of the building.

Conceptual Design Present Worth Study	
VE Alternative #3	
Building SF	105100
Cost of Maintenance, operations, etc.	$6.25
Interest Rate	12%
Compound Interest	0.134
Initial Costs	$28,452,480
Annual Costs	$4,744,197
Financing Costs	
Initial Costs	$17,853,362.15
Annual Costs	$588,822.75
Other Costs	
Design	$3,290,000
Indirect	$3,425,515
Alteration and Replacement	$1,522,899
Total Present Worth & Cost of Ownership	$59,877,276

Table 4-7: Alternative #3 LCC & Present Worth

4.3.2 Schematic Design Value Engineering Documentation

The WPI Residence Hall Committee performed their only value engineering analysis for the project after the completion of the schematic design and before the completion of the design development phase of the project. The committee met two separate times to work solely on a value engineering study for the project. Cannon Design, Gilbane Building Co, and WPI were present for the two separate meetings.

An overview of their value engineering study (denoted value management by Gilbane Co.) is seen in Table 4-8: Gilbane Value Management Results. The different divisions of construction were each analyzed and items which were above cost, below cost, and items that could be removed from the project were all recorded. From the table it can be seen that there was $754,000 of items that were reduced from the project but $947,700 worth of items were added a remainder of $1,080,870 worth of items were still pending on whether to be included or removed from the project.

VALUE MANAGEMENT LOG WPI - Residence Hall DATA DATE: January 15, 2007	COST TREND ITEMS	ACCEPTED ITEMS	PENDING ITEMS	REJECTED ITEMS	Comments
PROGRAM	-	-	-	-	
SITEWORK	170,000	-	178,000	511,000	Green Elements = +$100k
SUBSTRUCTURE	80,000	-	-	-	
SUPERSTRUCTURE	135,000	-	65,000	-	Green Elements = +$100k
EXTERIOR CLOSURE	676,000	-	275,000	-	Green Elements = +$140k
ROOFING SYSTEMS	-	-	300,000	-	Green Elements = +$300k
INTERIOR CONSTRUCTION	-	-	-	-	
EQUIPMENT / FURNISHINGS	-	-	-	-	
VERTICAL CIRCULATION	(150,000)	-	(59,000)	139,000	
PLUMBING	73,000	-	107,000	-	Green Elements = +$32k
FIRE PROTECTION	-	-	-	-	
HVAC	-	-	200,000	-	Green Elements = +$100k
ELECTRICAL	(98,000)	-	(55,500)	-	
OTHER	-	-	-	-	
SUB TOTAL	886,000	-	1,010,500	650,000	Green Elements = +$772k
SUMMARY FACTORS, (Fee, Insurance, CM Contin.)	61,700	-	70,370	104,000	
ADJUSTED TOTAL	947,700	-	1,080,870	754,000	
CONCEPT ESTIMATE TOTAL - 11-21-06	31,564,996	Original Design Contingency = $2.4 million			
TOTAL WITH COST TREND & ACCEPTED ITEMS	32,512,696				

Table 4-8: Gilbane Value Management Results [17]

One of the most interesting aspects about Gilbane's study was that along with identifying added, reduced, and pending costs they also identified areas where green building could be used and its correlated cost. Throughout the value management study Gilbane found eight different areas where green elements could be added and used as a LEED building point. Green elements were added in the sitework, superstructure, exterior closure, roofing system, plumbing, and HVAC and added a $772,000 to the project if they all were to be applied. Even though the green building elements add cost to the project, over the life cycle of the building they will provide better value both economically and environmentally [17].

The green sitework building elements considered in the value engineering analysis performed by the committee looked at adding a 10,000 gallon rain water collection tank which would cost around $100,000 and developing a rainwater collection system which would cost another $30,000. They also indicated adding a storm water recharge system designed by Cullinan Engineering with a cost which they were to determine. In the roofing division the committee looked at the option of adding a green roof, where grass would exist with a 2-4" depth, at a cost of $400,000 in addition to the presently designed roofing structure and other related elements. These are only a few examples of the environmentally friendly designs that the committee is attempting to add to the project. Even though these items add cost to the overall project the economic and environmental value that they provide throughout the life of the building are worth the additional cost [17].

The WPI Residence Hall Committee performed another value engineering analysis on March 28, 2007. Cannon Design, Gilbane Building Co., and WPI were all present and active throughout the meeting. They came up with a variety of cost savings items along with a few potential add-ons to the project. The cost savings items that were developed to be removed from the project are listed below.

Value Engineering	
COST SAVINGS	**Cost ($)**
Delete Window Washing Anchors	$40,000
Substitute Exterior Wall at dumpster area	$35,000
Eliminate 2nd access to roof	$15,000
Reduce Green Roof Area	$125,000
Reduce Interior Storefront	$75,000
Reduce Wood Paneling	$75,000
Reduce Benches	$25,000
Eliminate CMU columns at MEP rooms	$20,000
Reduce HVAC points for Windows	$75,000
Eliminate railing at Garage	$200,000
Total	**($685,000)**

Table 4-9: WPI Residence Hall Committee Value Engineering Study #2 Removed Items

Potential Adds	Cost
West Wall at garage is Precase full height	$125,000
Linoleum at living rooms vs. Carpet	$15,000
Add garbage disposals at all apartments	$15,000
Total	$155,000

Table 4-10: WPI Residence Hall Committee Value Engineering Study #2 Potential Add-ons

Even though the committee came up with potential items that could be added to the project they did still produce a cost savings of $430,000 of the initial costs of the project and most likely additional reduction in life cycle, energy, and space costs.

4.3.3 Design Development Value Engineering Analysis

The Design Development package was released on March 31, 2007 and the estimate was released on April 20, 2007. The WPI Residence Hall Committee had performed their own value engineering Study after the schematic design but had no plans of performing any other value engineering analyses. Thus a value engineering study will be conducted as a part of this research based on the design development documentation.

Description	Takeoff Quantity	Total Cost/Unit	Total Amount
SUBSTRUCTURE	103,782.00 Sqft	6.31 /Sqft	655,313
SHELL	103,782.00 Sqft	79.39 /Sqft	8,238,885
INTERIORS	103,782.00 Sqft	59.89 /Sqft	6,215,147
SERVICES	103,782.00 Sqft	90.66 /Sqft	9,408,668
EQUIPMENT AND FURNISHINGS	103,782.00 Sqft	2.21 /Sqft	228,800
BUILDING SITEWORK	103,782.00 Sqft	14.97 /Sqft	1,553,824
DEMOLITION	103,782.00 Sqft	2.25 /Sqft	233,900
GENERAL REQUIREMENTS (Below)	103,782.00 Sqft	/Sqft	

Estimate Totals

Description	Amount	Totals	Rate	›st per Unit
Subtotal, Trade Cost	26,534,537	26,534,537		255.68 /sqft
Escalation to Bid	*265,345*		1.000 %	*2.56* /sqft
Design Contingency	*796,036*		3.000 %	*7.67* /sqft
Preconstruction	*125,000*			*1.20* /sqft
CM General Conditions	*2,055,051*			*19.80* /sqft
CM General Requirements	*806,900*			*7.77* /sqft
CM Fee	*688,115*		2.250 %	*6.63* /sqft
CM Contingency	*928,709*		3.500 %	*8.95* /sqft
Total		***32,199,693***		***310.26*** /sqft

Figure 4-7: Gilbane's Design Development Estimate

Most value engineering studies aim to save around 5% in initial costs and 5% in life cycle costs, but as the project moves on and items become more specific there is less room to gain 5% reductions. In the design development stage the concepts and objective of the design have already been put in place. The value engineering study for design development will look at the various aspects of the documents and determine which items can be removed, reduced, replaced, or added which will still maintain the overall function and quality of the building but reduce the cost.

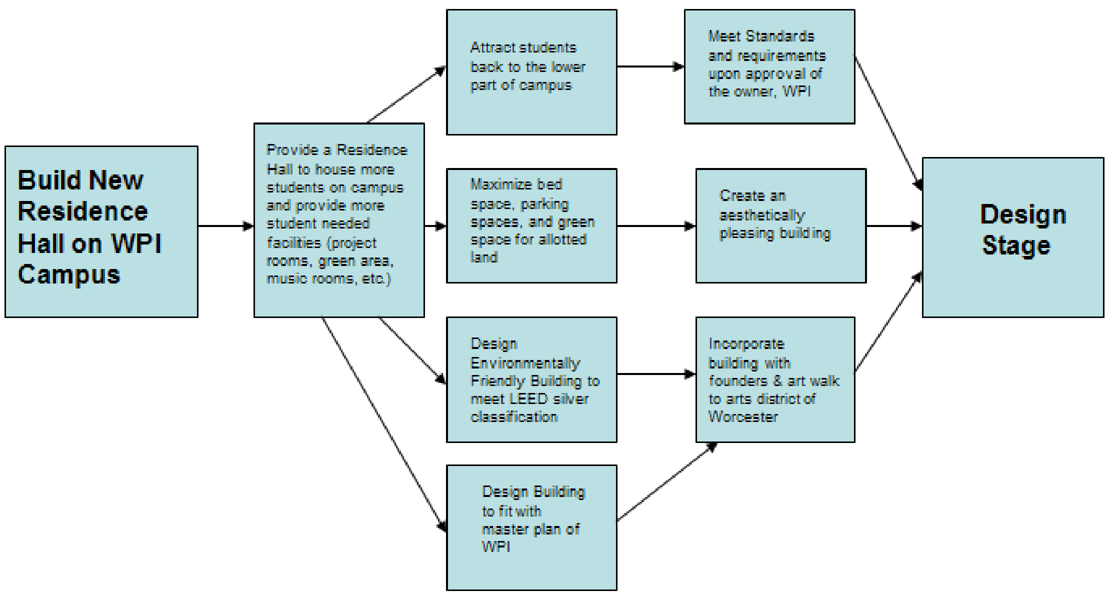


Figure 4-8: Fast Diagram of WPI Residence Hall

The first step in performing the value engineering study after the design development was gathering the information that would be needed in order to complete the study. The estimate that was produced by Gilbane along with the specifications and drawings from the design development were all utilized in order to complete the value engineering study. Once all the data was gathered it was necessary to create a Functional analysis system technique, known as a FAST diagram. The fast diagram can help to determine which functions for the project are primary, secondary, and so on. The FAST diagram for the project can be seen in Figure 4-8: Fast Diagram of WPI Residence Hall. The third phase in the value engineering study was creating and brainstorming for ideas. The estimate, drawings, and specs were searched through to try and pull out items which were no longer necessary for the project, did not meet project goals, where other alternatives could produce same function, or whose cost was not worth the benefits which it provided. A main focus during the creative process of the value engineering study was to have an high priority on environmental aspects of the design and see if any items could be changed which could produce more environmentally effective results but with equal function and quality.

After the creative process was completed the analysis phase of the study was then completed. In the analysis process present worth studies and cost models were developed to demonstrate the impact of the changes made from the value engineering study.

Design Development Present Worth			
Value Engineering			
Building SF	103782		103782
Cost of Maintenance, operations, etc.	$6.25	per ft^2	$6.25
Interest Rate	12%	7.47	12%
Compound Interest	0.134		0.134
Initial Costs	**$31,041,600**	47.90%	**32,199,693.00**
Annual Costs	**$4,744,197**	7.32%	**4,845,322.13**
Present Worth of Financing Costs			**20,786,102.02**
Initial Costs	**$20,204,663.36**	31.18%	20,204,663.36
Annual Costs	**$581,438.66**	0.90%	581,438.66
Other Costs			
Design	**$3,290,000**	5.08%	**3,290,000.00**
Indirect	**$3,425,515**	5.29%	**3,425,515.00**
Alteration and Replacement	**$1,522,899**	2%	**1,522,899.00**
Total Present Worth & Cost of Ownership	**$64,810,313**	100.00%	**$66,069,531**
Savings in LCC	**$1,259,218**	**2%**	**SAVINGS**

Figure 4-9: Design Development Present Worth Model

It was found that the present worth of the building as it stood was $64,184,758. If the value engineering costs were to be integrated and followed through the present worth of the building would change by 2% and provide a reduction in cost of $64,810,313.

After the analysis process of the value engineering was performed the last phase or presenting the results can be produced. The cost and affect of implementing the results can be seen in the cost analysis sheet provided in Figure 4-10: Design Development Value Engineering Cost Savings.

Design Development Value Engineering Study				
Items	Total Cost Savings	Cost Savings	Cost Additions	Addition action
Remove Door Operators	$15,000.00	$15,000.00		
Remove Horizontal Shades	$50,000.00	$50,000.00		
Remove Mailbox Unit	$7,500.00	$7,500.00		
Remove Storm Drainage 12" piping (average)	$22,500.00	$90,000.00	$67,500.00	Replace with 8" Storm Drainage piping
Remove Concrete Kneewall	$19,250.00	$19,250.00		
Reduce sidewalk base from 8" to 6"	$3,750.00	$15,000.00	$11,250.00	replace with 6" gravel base
Reduce Chilling Generator to 80 ton w/VFD	$31,040.00	$155,200.00	$124,160.00	replace with 80 ton w/VFD
Remove Bathtub	$2,297.30	$2,297.30		
Rmove Garbage Disposal Connections	$5,395.00	$5,395.00		
Replace Granite Curbing at Dock w/Recycled Rubber Curbing	$3,000.00	$5,000.00	$2,000.00	allow for recycled rubber curbing
Replace Curbing on the thru-road w/ Recycled Rubber	$3,000.00	$5,000.00	$2,000.00	allow for recycled rubber curbing
Redice Gas Boiler mbh output	$32,800.00	$82,800.00	$50,000.00	allow
Remove Ornamental Gate	$5,000.00	$5,000.00		
	$200,532.30	$457,442.30	$256,910.00	
Total VE Savings	$200,532.30			
Total Project Cost at Design Development	$32,199,693			
Projected VE Savings	0.62%			

Figure 4-10: Design Development Value Engineering Cost Savings

After going over the design development documents of the WPI Residence Hall there were a variety of items that were found could be replaced, removed, or added which would help maintain the function and quality of the building while reducing its cost, thus maximize its value. The door operators were found not to meet any of the function requirements of the building and thus could be removed. The horizontal shades that were included in the estimate were recommended to be removed in order to provide more light to the building. This would hopefully add to increasing the daylight to possibly more than 75% of the spaces. Another option in addition to removing the horizontal shades would be to consider which areas of the building actually need the vertical shades also instead of considering all windows to have the shades.

Because a parking garage will also be on the same lot of the building, for the building costs there is not that much pavement or curbing that is necessary. Although one possible option that was recommended to be considered for the all the curbing for the project was to use recycled rubber instead of granite for the dock and on the thru-road for the church. By doing this the cost for the curbing would be reduced extremely and at least One LEED point would be gained for using recyclable materials.

The average diameter for storm water drainage is 12”, but because the WPI Residence Hall has taken on more environmentally effective water retention facilities like a white PVC roofing system, storm water collection tank, and the green roof the average storm water runoff will be reduced thus a smaller diameter pipe will be able to handle the storm water runoff. When Gilbane built the Bartlett Center on WPI last year they included a concrete knee wall with an integrated bench area. It functions to provide more seating for outside the building but rarely is it used and thus its function and benefit are not as effective compared to the cost that is associated with it, thus it was recommended to be removed.

Per code the standard sidewalk depth for concrete is 6”. The sidewalk gravel depth was indicated to be 8”, and it was recommended to be reduced to a depth of 6” which produced a cost savings of $3750. With the integration of the green roof to the WPI Residence Hall it will produce a savings of almost 10% in energy costs and will produce definite cooling and heating energy reductions. From these results it can be justified that the Chilling generator can be reduced from needing 100 ton w/VFD to 80 ton w/VFD. Another energy efficient option was reducing the gas boiler mbh output from 1000 to 900 because of the same efficient savings in cost and energy from the effects stated below. This hits two LEED points, one for minimizing the energy performance and another for optimizing energy performance.

In the schematic design value engineering it was questioned on whether or not the garbage disposals should be included in the building and after deliberation it was decided that they were not. Thus there needs to be no connection for garbage disposals in the building and thus this produces a reduction in cost by $5395. The bathtub was running a connection of over $2000 and did not provide any necessary functions in sustaining the design or adding to it by any environmental means so it was recommended to be removed. Another item of concern was the single mailbox unit. It cost $7500 and did not affect the quality or function nor did it have any environmentally friendly aspects of its integration within the build, thus it was recommended to be removed. The last item which was considered for removal was the ornamental gate. By introducing a gate to the building's area it restricts the concept of open space. Therefore its addition to the project does not suit well with the project goals or functions and therefore would be recommended to be removed.

The design development value engineering study provided results in reducing cost, providing more environmentally friendly alternatives, and increased value while maintaining the quality and function of the WPI Residence Hall. The conclusions of the design development value engineering study can be seen in the next chapter.

5 CONCLUSION

Now that the background, methodology, and investigation and analysis sections of the research have been presented it is necessary to provide the results of research and the associated conclusions. Data was collected in relation to three different analyses involving informational models, project integration, and value engineering. The results and conclusions of these different concepts are provided in the following paragraphs.

5.1 INFORMATIONAL MODEL RESULTS

The WPI Residence Hall Committee did not have any specifically outlined informational models. Even though they did not have established informational models the same concepts which informational models promote and clarify were performed by the committee. Each party, Cannon Design, WPI, and Gilbane attended the weekly meetings and all people in the parties for the most part were actively involved in the discussions during the meetings and it was during these discussions that decisions and suggestions related to the project were made.

One of the most effective tools that the WPI Residence Hall Committee used was the use of information technology via the my.wpi site. By using this technology all the documents that related to the WPI Residence Hall were available online for the students who were conducting research on the project. It made it easy to obtain information related to the project without having to go through a variety of people to get the information that was needed to complete the research, and thus made completing the research for the project much easier than if the my.wpi site was not used.

Since all parties of the WPI Residence Hall committee were so active and involved with the project and one another it was not necessarily a negative factor that they did not utilize product, process, or management models throughout the project. Those models are used to provide the information, concepts, and ideas that the WPI Residence Hall Committee already had. Thus due to the committee's high level of effectiveness despite the lack of use of informational models (besides the my.wpi site) proved that informational models do not necessarily need to be used in order to produce positive results in terms of product, process, and management.

5.2 VALUE ENGINEERING ANALYSIS RESULTS

5.2.1 Conceptual Design Value Engineering Study Results

The goals of the conceptual design VE study were to achieve a 5% savings on the initial costs of the building and a 5% savings over the LCC of the building. Lets look at how the different savings that the alternatives produced. It can be seen that the only alternative that met the VE Study goals of producing a 5% reduction in initial costs and a 5% reduction in Life Cycle Costs was Alternative 3. Alternative 3 exceeds the initial savings goal by 5% and the LCC by almost 3%.

Therefore it can be concluded that to provide a savings of 10% in the initial building cost and a savings of 8% in the LCC of the building incorporating alternative 3 into the concept of the schematic design would help produce the most savings while only reducing the cost per room by $20 and decreasing the square footage per room by about 3%. Therefore in comparing the small changes that need to be made to the project to the large savings that result from these changes it can be seen that alternative 3 is a valuable option to produce savings while still maintaining quality.

Alternative	Initial Savings %	LCC Savings %
VE GOAL	5%	5%
VE Alternative #1	3%	5.60%
VE Alternative #2	4%	2.26%
VE Alternative #3	10%	7.90%

Table 5-1: VE Alternative Overall Savings

5.2.2 Schematic Design Documented Value Engineering Conclusions

The value engineering analysis that the WPI Residence Hall Committee conducted did indeed indicate areas where items could be reduced but the process through which the value engineering study was performed was not necessarily ideal. One of the greatest benefits of performing a value engineering study is to see how the items removed affect the various costs of the project in terms of construction costs, life cycle costs, energy costs, and space costs. Especially considering the silver LEED certification that the project is aiming for it would have been highly useful to see how the energy costs of the building would be affected by some of the changes.

The changes that were made which affected the energy costs of the building most likely would have also affected the life cycle costs of the building. Even though none of the life cycle, energy, or space cost models were created from the items that were chosen to be removed and those that were added they will provide more environmentally friendly features of the building and be more cost effective over the life of the building.

5.2.3 Design Development Value Engineering Results

The value engineering study that was performed for the design development stage produced a direct cost savings of .62% over the initial costs of the building and produced a 2% savings in cost over the next 20 years of the building as determined by the present cost method of analysis. The percentage of savings were slightly lower than the conceptual and schematic value engineering studies because there are more specific items that cannot be removed and a value engineering study has already been completed so there are less items to be altered, reduced, or removed.

The value engineering study also came up with three different proposals which were related to the LEED certification of the building and could add to the total point value and thus overall rating for the building. The value engineering study found 13 items which could be removed and 3 of the items would be effective in meeting certain LEED point requirements. The five different LEED point requirements that could be met through these would be of optimize energy performance by minimizing energy performance, use of Recycled content, increase daylight and views, and Development Density and Community Connectivity. These different aspects can be seen below.

Yes	?	No		Sustainable Sites	Responsibility
8	4				
Y			Prereq 1	**Construction Activity Pollution Prevention**	CE
1			Credit 1	**Site Selection**	CE
1			Credit 2	**Development Density & Community Connectivity**	CE
			Credit 3	**Brownfield Redevelopment**	
1			Credit 4.1	**Alternative Transportation**, Public Transportation Access	CD
1			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	CD
	1		Credit 4.3	**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	CD
1			Credit 4.4	**Alternative Transportation**, Parking Capacity	CD
			Credit 5.1	**Site Development**, Protect of Restore Habitat	
	1		Credit 5.2	**Site Development**, Maximize Open Space	CD
	1		Credit 6.1	**Stormwater Design**, Quantity Control	CE
1			Credit 6.2	**Stormwater Design**, Quality Control	CE
	1		Credit 7.1	**Heat Island Effect**, Non-Roof	CD
1			Credit 7.2	**Heat Island Effect**, Roof	CD
1			Credit 8	**Light Pollution Reduction**	MEP-CD

Figure 5-1: LEED Point Qualification #1

6	2			Energy & Atmosphere	
Y			Prereq 1	**Fundamental Commissioning of the Building Energy Systems**	Cx- RDK
Y			Prereq 2	**Minimum Energy Performance**	MEP-CD
Y			Prereq 3	**Fundamental Refrigerant Management**	MEP-CD
4	1		Credit 1	**Optimize Energy Performance**	MEP-CD
			Credit 2	**On-Site Renewable Energy**	
1			Credit 3	**Enhanced Commissioning**	Cx-RDK
1			Credit 4	**Enhanced Refrigerant Management**	MEP-CD
			Credit 5	**Measurement & Verification**	
	1		Credit 6	**Green Power**	RMEC

Figure 5-2: LEED point qualification #2

6	1		Materials & Resources		
Y			Prereq 1	**Storage & Collection of Recyclables**	CD
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	
			Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	
			Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	
1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	GBC
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	GBC
			Credit 3.1	**Materials Reuse**, 5%	
			Credit 3.2	**Materials Reuse**,10%	
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	GBC
1			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	GBC
1			Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regic	GBC
	1		Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regic	GBC
			Credit 6	**Rapidly Renewable Materials**	
1			Credit 7	**Certified Wood**	GBC

Figure 5-3: LEED point qualification #3

The associated cost with each of these LEED points by removing or reducing their output is $113,500 plus the reduction in operation and maintenance costs of the building over its life. By removing the ornamental gate from the building design it creates more community connectivity for the surrounding area of the building. By using recycled rubber for the curbing sections of the building a point for the Materials and Resources section of the LEED design could be achieved. Lastly by reducing the heating and cooling capacities their energy performances were both minimized and optimized for the building. Since the project already meets all of these credits it is possible that having these recommendations on top of the existing functions which provide the credit, if one of those other items fails due to some issue with the project, the associated LEED point will not be lost because there will exist another item in the project which also qualifies for that point. Thus through these recommendations it is possible to sustain the LEED point total for the WPI Residence Hall even if there were to exist problems which might result in a loss of points.

In conclusion, the value engineering study for the WPI Residence Hall produced results which demonstrated that even in the later stages of design value engineering is still an effective management tool that can help assess the function versus value aspect of the project and produce savings in cost, energy, and space. The value engineering study from the design development stage could be used by the WPI Residence Hall committee as a starting point for the committee to begin a value engineering study for the design development phase. If this was done it is possible that the demonstrated cost, environmental, and value results could be achieved and seen in the WPI Residence Hall Project.

5.3 PROJECT INTEGRATION FINDINGS

There were two different sections of the project integration analysis, the meeting analyses and the project integration questionnaire analysis. The meeting analyses provided insight into the inner workings of a project whereas the data from the project integration questionnaire led to the development of a way to measure the Total Project Integration Level of a project.

5.3.1 Meeting Analysis Conclusions

The information taken from observing the WPI Residence Hall Committee meetings was used to identify areas of integration within the project and analyzed both the negative and positive effects that integration had or could have had on the project.

At the third meeting mentioned in the analysis section, upon hearing within the first half hour of the meeting that President Berkey did not like any of the building design schemes that Canon had developed in the past few weeks was quite astonishing. The design criteria that they based their design off of were from information that administrators had already supposedly agreed on. To find that the designs they presented to the WPI Residence Hall Committee were completed in 30 hours questions such as how much time did they put in to the past designs they created and how much cost was it for them to create those designs come to mind.

If President Berkey had been briefed on every meeting of the Residence Hall would it have been possible that earlier in the design phase the designs they developed in 30 hours could have been developed? Or is it possible that if President Berkey's opinion had been involved earlier due to his earlier involvement would it have been possible that the design phase would have been completed earlier, seeing it only took 30 hours to create the new building design? Canon's Project Manager said that if President Berkey's involvement was greater towards the beginning of the design phase it may have reduced the possibly of redesign and the schedule being delayed by one week.

On a positive note though, Canon's Project Manager noted that the amount of involvement that WPI has in the project (from students, students doing projects, teachers, ATC, and other administrators) adds greatly to developing a design that is agreed on not just by the top administrators but as a school as a whole. He said that it is not often that you find such a highly integrated amount of people from the owner, and he thinks that it will ultimately provide the best building for the school. He also said that the interaction between WPI and Canon has been good and that due to its positive nature it makes meeting their demands more feasible.

The conclusions that were able to be made from attending the New WPI Residence Hall meetings were that all the factors which affect the integration of the project could be witnessed first hand. It was obvious that the design process so far was moving on smoothly and with a fair amount of integration and collaboration from all parties. The only major factor that was identified that affected the project was that there was weeks and weeks worth of design done and the entire building had to be redesigned because President Berkey did not like any of the designs.

In conclusion, if President Berkey had been slightly more involved or informed during the conceptual design phase then it may not have taken as long to produce the conceptual design. Even though the redesign did not have a detrimental effect on the overall project process at the beginning it did create a slight delay in the design of the project. Therefore in the future, involving and releasing information to all especially through a mass used electronic format would have been slightly useful to everyone and in the future Cannon should look at creating and using an electronic form of transfer of information to the project team.

5.3.2 Project Integration Questionnaire Conclusions

The project integration analysis of the factor questionnaire looked at various ways in which a project was affected by the usage and importance level of integration factors. The usage and importance levels were ranked on the same factors but asked to rank to different objectives, yet what was seen by comparing the usage and importance levels side by side in a bar graph was that of the highest ranked usage levels and importance there existed three common factors in the top factor rankings. These factors were factor #1"enlightened and enthusiastic client," factor #2 "knowledgeable client about project processes & integration," and factor #10 "adequate resources and technical skills." What was concluded about these results was that factor 1, 2, and 10 were the factors which had the highest usage and were of the most importance to driving project integration in the WPI Residence Hall project as indicated by the sample population. If other projects look to apply factor 1, 2, and 10 to their projects they may also be able to increase their levels of project integration.

Other results that were produced from the integration analysis involved whether the usage and importance levels were correlated with one another. A Pearson Correlation was performed and for the average usage and importance levels it produced a correlation coefficient of .7678. The closer the correlation coefficient is to 1 the greater the correlation is between the two variables. From this it was concluded that there existed a 76.78% correlation between the usage and importance factor levels, and there existed a 76.78% chance that if the usage level increased or decreased so did the importance level, and vice versa. What really helped to demonstrate this were the scatter plot and the line of regression for the two variables. This provided a visual understanding and consensus for understanding how the usage levels and importance levels of integration factors were related. Even though the Pearson Correlation shows the correlation between usage and importance levels it does not show cause and effect, thus usage levels do not cause integration levels to increase or decrease nor do integration levels cause usage levels to decrease or increase. It is possible that other causes could exist which explain the relationship. All the Pearson Correlation says is that the two variables are correlated with one another.

Since there were three different parties that were involved in the sample size and each party held different positions in the project and thus could have different opinion in terms of ranking usage and importance levels, the different samples were categorized according to which party they represented. After they were categorized a Pearson Correlation was performed measuring their opinion on factors versus another party's opinions. It was found that the party that produced the lowest correlation was between WPI and Cannon, which had a correlation coefficient of 0.22 which is quite low in comparison to the correlation coefficients of .43 between Gilbane and Cannon and .41 between Gilbane and WPI. From this it can be seen that there existed very little correlation between what Cannon's opinion was and what WPI's opinion was. Although since Cannon's group only consisted of one sample that possibly could explain for the low level of correlation. Thus due to the low sample amount it is difficult to accurately determine if there existed any biases amongst the different parties.

Maximizing the use of driving integration factors is essential to optimizing the use of integration in a project; therefore identifying areas where integration can be increased is an effective measure to be analyzed. The project integration analysis looked at this measure by conducting a line plot of the usage and importance levels for both driving factors and deterrent factors. For the driving factor plot any areas where the importance levels were closer to 1 than the usage levels indicated a factor where integration could be increased. For the deterrent factor plot any areas where the usage levels were closer to 1 than the importance levels indicated areas where deterring integration could be reduced. This method proved effective as it provided that the importance level for factors 3, 8, 11, 12, 13, 25, 28, and 29 should be increased in order to help to increase the level of integration in the project. For the deterrent factor plot, if the usage levels of factors 6, 20, and 30 can be reduced then it is possible that the deterrent factors of integration can be reduced for the project and add to increasing the project integration overall.

Even though looking at the graphs identified areas where usage and importance levels were higher than one another in order to identify areas of integration this does not indicate the only areas where other driving or deterrent factors importance or usage levels could be increased or decreased to provide more project integration for the project. The method performed above analyzes the most pertinent driving and deterrent factors which can affect project integration.

The last conclusion that can be made about the integration analysis is the Total Project Integration Level (TPIL). This concept provides a way to demonstrate the overall usage and importance level of the various factors and how driving and deterrent factors are related to one another and the entire project. Based on the method described in the analysis section the WPI Residence Hall project produced a usage TPIL of 1.08 out of 5 and an importance TPIL of .73 out of 10. In order to provide better integration within the project providing more information on the project integration methods, driving and deterrent factors, and the effects that it has on a project to the project team could possibly work.

Even though the project integration that was observed throughout the WPI Residence Hall Project there did exist some variation in the samples answers, only 50% of the questionnaires were returned, and some subjects were not quite knowledgeable about project integration and possibly could not have answered the questionnaire to the best of their ability because of that. Thus the results from this integration analysis are to provide a new understanding of how to analyze, measure, and place value on the levels of project integration in projects.

5.4 CIVIL ENGINEERING & MATH INTEGRATION MODEL

The topic of this research was developed out of a desire to find a subject which could encompass research in both areas of mathematics and civil engineering. After working together with a mathematics professor and a civil engineering professor a project was created which looked at developing ways to (1) mathematically model the affects of integration and (2) investigate & develop a way to measure and or quantify project integration levels in a project.

5.4.1 Mathematical Research Contribution

As stated earlier, a mathematical research project was conducted in conjunction with project to model the way in which project integration affected a project. After looking at various ways to approach the model it was determined that basing the model off of the critical path method would produce the best environment for the model. In order to understand how to develop the model an overview of what a network is, how the critical path is a network, how the critical path works, and what the linear programming formulation is for the critical path method [16].

Once the background of the mathematical research was completed the methodology by which the mathematical model was going to be developed by was given. After researching a variety of ways in which to demonstrate the effects of project integration it was found through classifying tasks according to integration through node collapse and node leaks were the best methods. First the civil engineer would need to determine which tasks were involved in integration or could possibly involve integration and then they could be classified according to exactly what is affected by or caused the integration [16].

There were two separate networks that were used to produce the model, a task oriented network and an object oriented network. The task oriented network is where node collapse occurs. Collapsing is caused by the collaboration of independent tasks resulting in the absorption of one task into the other causing the duration of both tasks to be affected. As a result of the collapsed nodes, the number of nodes and arc in both LPs are reduced. For a single collapse, the number of nodes is reduced by one and the number of arcs in the task oriented network is reduced by two. Due to this reduction in nodes and arcs, the number of constraints in the network flow and time/cost LPs are condensed and the number of variables affecting the objective functions is cut. Refer to Figure 5.-1 [16].

4 variables

$$\max \; \tau_1 x_{12} + \tau_1 x_{13} + \tau_2 x_{24} + \tau_3 x_{34}$$

4 constraints

$$\begin{aligned} -x_{12} - x_{13} &= -1 \\ x_{12} - x_{24} &= 0 \\ x_{13} - x_{34} &= 0 \\ x_{24} + x_{34} &= 1 \end{aligned}$$

2 variables

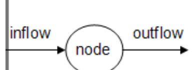
$$\max \; \tau_1 x_{12'} + \tau_{2'} x_{2'4}$$

3 constraints

$$\begin{aligned} -x_{12'} &= -1 \\ x_{12'} - x_{2'4} &= 0 \\ x_{2'4} &= 1 \end{aligned}$$

Figure 5-4: Task Oriented Network Node Collapse Example

The object oriented network is where the concept of leaks in nodes exists. Leaks are caused by the collaboration of independent tasks resulting in one of those tasks' duration to be affected. Occur when presence of collaboration (or lack of) causes the inflow of a node to not equal its outflow in the network flow LP. Due to this inequality, the right-hand-side of the constraints of network flow LP is altered. To enforce balance in the network, the sum of the leaks is subtracted from the first node. The value of these leaks would be determined by the Civil Engineer, denoted in the LP as l_j, where j = task affected. A visualization of how this process works is provided below [16].



inflow - outflow ≠ 0

$$\begin{aligned} -x_{12} &= -1 - \sum l_i \\ &\;\;\vdots \\ x_{ij} - x_{jk} &= l_j \end{aligned}$$

$$\min t_n + l_j t_j - (1 + \sum l_i) t_o$$

Figure 5-5

The developed concept of collapsed nodes and leaky nodes from the task oriented and object oriented network produce a new network which is the mathematical model that demonstrates how project integration affects a project [16].

5.4.2 Civil Engineering Research Contribution

The research of this civil engineering project was conducted in conjunction with another project which was mathematically based and was attempting to model the way in which project integration affected a project. What turned out to be required of the civil engineer in order for a value to be output by the mathematical model was to determine exactly how to measure project integration. In the project integration analysis section of this research paper a Total Project Integration Level in terms of usage and importance was developed which is useful in understanding the overall level of project integration.

What is required by the newly developed mathematical model on project integration is how to measure project integration levels at exact areas and points where integration occurs and then how to represent that value so that it is represented correctly back in the mathematical model. Therefore even though the research from this civil engineering research project developed a way to measure project integration, it was not applicable to the mathematical model. In order to produce the correct value to represent project integration as indicated in the mathematical research done in conjunction with this research, additional research involving the collaboration between mathematicians and civil engineers would need to occur.

6 FUTURE RESEARCH

The last section of this paper is devoted to providing recommendations for future research as related to the research presented in this paper. The research in this paper has provided insight on project integration and value engineering. By following the WPI Residence Hall project it was possible to apply the various methods that were developed to analyze project integration and demonstrate how value engineering can be an effective management tool.

Future research that could be completed to build on the research of this project would be to investigate more in the process of identifying project integration factors, how to evaluate these factors, and additional and more effective ways to measure and quantify project integration. In addition further research should be conducted together involving civil engineers and mathematicians in order to optimize the research capabilities of developing a model which can accurately reflect the affects of project integration on a project and model the associated project integration level.

7 REFERENCES

1. Mitropoulos, Panagiotis, Tatum, C.B. "Management Driven Integration." Journal of Management in Engineering. January/February (2000).
2. Puddicombe, Micheal S. "Designers and Contractors: Impediments to Integration." Journal of Construction Engineering and Management. September (1997).
3. Salazar, Guillermo F. "A Planning and Scheduling Model for Mass Production in Housing Construction." Diss University of Toronto, 1977.
4. Sears, James R. "Impact of Construction Delivery Systems and Remuneration Methods On Cost, Schedule, and Quality for Educational Building Construction." Diss. Worcester Polytechnic Institute, 1995. Worcester: WPI, 1995.
5. Pilcher, Roy. "Principles of Construction Management." McGraw Hill. London, England 1967.
6. Garvin, Michael J. "Role of Project Delivery Systems in Infrastructure Improvement." Construction Research Congress. 2003.
7. Sader, Roula E. "Design-Build in the Commonwealth of Massachusetts." Diss. Worcester Polytechnic Institute, May 2003.
8. "History." www.gilbaneco.com. 2007. Gilbane Building Company. 11 April 2007. http://www.gilbanebuilding.com/inside/history.aspx
9. "Fast Facts." www.cannondesign.com. 2007. The Cannon Corporation. 11 April 2007. http://www.studyguide.org/MLAdocumentation.htm
10. Brown, James. Value Engineering: A Blueprint. Industrial Press, Inc. New York, NY 1992.
11. Dell'Isola, Alphonse. "Value Engineering: Practical Applications…for Design, Construction, Maintenance, & Operations." R.S. Means Company, Inc. Kingston, MA 1997.
12. Park, Richard. "Value Engineering: A Plan for Invention." CRC Press. Boca Raton, FL 1999.
13. Stumpt, Ganeshan, Chin, Liu. "Object-Orientated Model for Integrating Construction Product & Process Information." Journal of Computing in Civil Engineering. July (1996).
14. Kumaraswamy, Ling, Rahman, Phng. "Constructing Relationally Integrated Teams." Journal of Construction Engineering and Management ASCE. October (2005).
15. Canon Design. WPI New Residence Hall Conceptual Design Report.
16. LaHart, Heather, Meko Mark. "Optimization Methods for Project Integration." WPI. Worcester, MA 2007.
17. Gilbane Building Co. "Value Management Log." WPI Residence Hall Building. April 2007.
18. Oberlender, Garold D. "Project Management for Engineering & Construction." McGraw-Hill Higher Education. United States 2000.

8 APPENDIX

8.1 Project Integration Driving Factor Questions

Worcester Polytechnic Institute (Owner)

	Driving Factors
1	Enlightened and enthusiastic client
2	Knowledgeable client (about project processes and RC)
3	Client's initiative
4	Learning about RC approaches before contractings (all parties)
5	Co-operative learning within project organization
6	Familiarity/previous relationships with/among other parties
7	Repuation in the industry (each party)
8	Willingness/enthusiasm of involved parties
9	Previous experience in RC approaches (each party)
10	Adequate resources and technical skills (each party)
11	Previous performance records on hard factors like time, quality, safety (each party)
12	Compatible organization culture of involved parties
13	Interpersonal relations/cultural harmony (individual)
14	Previous performance records on soft factors like joint decision making, provlems, issues, etc (each party)
15	Short listing capable and compatable potential project paartners istead of price only consideration
16	Disclosing project information to potential partners at early stages of project for optional feedback
17	Seeking specific inputs on constructibility, construction methods, materials fom potential partners
18	Selecting the best possible, capable, and compatible project team from potential partners
19	Bringing contractor, major subs and suppliers into the project team for longer term interactions
20	More workshops for better interactions to build trust/reliability
21	Use of single point responsibilty
22	Group combined responsibility as against individual responsibility
23	Role of an independent full time facilitator in building trust, teamworking and can do spirit
24	Role of Project Manager as facilitator as per item above given that PM has best understanding and control
25	Requirement for an indpendent full time facilitator to supplement PM
26	Company training policy to build adaptable individuals for working with diverse partners (each party)
27	Corporate strategy of building trust with potential partners by doing the righ thing and meeting time & cost
28	Use of Information Technology
29	Use of Informational Models
30	Use of Contractual Agreements that Promote Integration
31	Extent of Organizational Structure & Cultural Atmosphere
	*Factor Usage level: *5 = none, 4 = low, 3 = moderate, 2 = strong, 1 = very strong*
	**Level of Importance for Promoting/Deterring Integration: *1 = most important 10= least important*

8.2 *Project Integration Deterrent Factor Questions*

	*Factor Usage level: *5 = none, 4 = low, 3 = moderate, 2 = strong, 1 = very strong*
	**Level of Importance for Promoting/Deterring Integration: *1 = most important 10= least important*
	Deterrent Factors
1	Lack of client's knowledge about projec process and RC
2	Lack of commitment from top management: client
3	Lack of commitment from top management: other party
4	Lack of client's initiatives
5	Bureaucratic client organization
6	Stringent/incompatible public sector rules and regulations
7	Public secotor accountability concerns
8	Price only' selection methods
9	Commercial pressures on contracting parties
10	Oportunistic behaviour of one or more contracting parties
11	Lack of trust and reliability among contracting parties
12	Unwilling and unenthusiastic participation of contracting parties
13	Interpersonal and cultural clash (individual level)
14	Incompatible organzational culture
15	Absence of any risk reward plan
16	Separate and unrelated risk reward plans for different parties
17	Exclusion of consultants in risk reward plan
18	Exclusion of major subcontractors in risk reward plan
19	Exclusion of major suppliers in risk reward plan
20	Unfair risk reward plan
21	Lack or absence of contractural relations between client and major subcontractors
22	Lack of any relationships or communications between client and major suppliers
23	Lack of relationships or communications between subcontractors and suppliers
24	Resistance of contracting parties to integrated project culture\
25	Failure to share information among contracting parties
26	Presistence of master and slave concept
27	Uneven commitment of contracting parties
28	Discontinuation of open and honest communication
29	Improper planning, design errors and omissions
30	Potential legal liabilities in resolving non contractual issues

8.3 Questionnaire – Driving Factor Average Usage Level Results

Usage Levels						
Gilbane Superintendent	Gilbane Ass. Proj. Engineer	Gilbane-Project Executive	WPI-Dean of Students	WPI - Student	Cannon - Project Manager	
Sample 1	Sample 2	Sample 4	Sample 3	Sample 6	Sample 5	Factor Mean
1	2	1	1	1	1	1.16666667
1	2	1	2	2	2	1.66666667
1	3	1	3	3	2	2.16666667
2	4	2	4	4	2	3
2	4	2	2	5	2	2.83333333
2	2	2	3	1	4	2.33333333
1	4	3	2	2	3	2.5
1	2	2	1	2	1	1.5
1	1	3	2	3	2	2
1	1	1	2	4	2	1.83333333
2	1	2	2	5	2	2.33333333
1	4	2	1	3	2	2.16666667
1	3	2	1	4	1	2
1	3	2	2	5	2	2.5
2	3	2	3	4	2	2.66666667
3	3	2	5	1	2	2.66666667
1	3	2	5	2	1	2.33333333
1	3	1	5	1	1	2
1	3	2	5	1	1	2.16666667
2	4	3	4	4	2	3.16666667
2	2	3	4	2	3	2.66666667
2	2	2	2	3	1	2
1	4	3	4	5	3	3.33333333
0	4	2	2	4	1	2.16666667
1	4	3	4	5	3	3.33333333
2	3	3	3	2	3	2.66666667
1	3	2	3	4	2	2.5
2	3	3	2	4	2	2.66666667
2	3	3	5	1	2	2.66666667
2	3	3	3	1	3	2.5
2	2	3	5	1	2	2.5

8.4 Questionnaire - Deterrent Factor Average Usage Level Results

Gilbane Superintendent	Gilbane Ass. Proj. Engineer	WPI-Dean of Students	Gilbane-Project Executive	Cannon - Project Manager	WPI - Student	
Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	
		4	2	1		2.33333333
		4	1	2		2.33333333
		4	2	2		2.66666667
		4	2	2		2.66666667
		4	1	2		2.33333333
			1	2		1.5
			2	2		2
		4	3	1		2.66666667
		4	3	3		3.33333333
		4	2	1		2.33333333
		4	1	1		2
		4	2	1		2.33333333
		4	2	2		2.66666667
		4	2	2		2.66666667
			3			3
			3			3
			3			3
			3			3
			3			3
			2			2
			4			4
		4	3			3.5
		4	2			3
		4	2	1		2.33333333
		4	2	1		2.33333333
			4			4
		3	4	1		2.66666667
		5	1	1		2.33333333
		4	2	2		2.66666667
			2	2		2
						#DIV/0!

8.5 *Questionnaire – Driving Factor Average Importance Level Results*

Gilbane Superintendent	Gilbane Ass. Proj. Engineer	Gilbane-Project Executive	WPI-Dean of Students	WPI - Student	Cannon - Project Manager	
Sample1	Sample 2	Sample 4	Sample 3	Sample 6	Sample 5	Importance Mean
2	2	1	2	1	1	1.5
1	3	1	3	4	5	2.833333333
4	5	3	3	7	5	4.5
6	6	3	2	2	5	4
3	7	2	3	1	1	2.833333333
5	3	3	7	2	4	4
5	6	4	5	8	8	6
7	3	2	3	3	1	3.166666667
10	1	3	1	2	3	3.333333333
5	2	2	2	2	1	2.333333333
5	3	3	2	1	3	2.833333333
7	6	2	2	4	2	3.833333333
10	6	2	2	5	1	4.333333333
5	6	2	3	2	3	3.5
7	6	3	4	3	2	4.166666667
5	7	3	7	3	2	4.5
1	7	3	7	4	3	4.166666667
1	7	2	7	6	1	4
5	8	3	7	5	2	5
10	8	4	6	3	2	5.5
1	8	4	7	8	2	5
5	4	2	2	2	2	2.833333333
7	5	5	5	10	4	6
5	9	3	5	3	2	4.5
9	9	6	5	6	5	6.666666667
5	9	3	1	7	5	5
7	9	3	1	6	5	5.166666667
70	10	5	5	1	3	15.66666667
7	10	5	5	1	3	5.166666667
5	10	6	3	1	5	5
2	10	2	2	2	2	3.333333333

8.6 *Questionnaire – Deterrent Factor Average Importance Level Results*

Gilbane Superintendent	Gilbane Ass. Proj. Engineer	WPI-Dean of Students	Gilbane-Project Executive	Cannon - Project Manager	WPI - Student	
Sample1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Importance Mean
		3	2	4		2.833333333
		3	1	3		2.333333333
		3	1	2		2.166666667
		4	2	3		2.916666667
		5	2	3		3.083333333
			3	4		2.833333333
			3	4		3
		2	3	2		2.416666667
		4	4	3		3.583333333
		2	4	1		2.333333333
		1	2	1		1.5
		3	2	1		2.083333333
		2	2	3		2.416666667
		3	3	3		2.916666667
			5			4
			5			4
			6			4.5
			6			4.5
			6			4.5
			3			2.5
			7			5.5
		5	7			5.166666667
		3	3			3
		3	3	1		2.333333333
		2	2	2		2.083333333
			8			6
		3	4	1		2.666666667
		1	2	1		1.583333333
		1	2	3		2.166666667
			5	4		3.666666667
						#DIV/0!