2011

Penn State AE Senior Thesis

The West Fuala Expansion

Abu Dhabi, PA

Technical Report 3

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Monday, November 14, 2011
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Executive Summary:

The purpose of Technical Assignment 3 is to explore an identify areas that could be improved in the West Fuala Plant Expansion. This would be done by exploring and detailing in many aspects and areas of the project being constructed currently in order to be able to come up with a proposal of a better improved design. The topics that will be addressed in this report that will help identify features that could be improved are the following: Constructability Challenges, Schedule Acceleration Scenarios, and Value Engineering Topic. In addition, Critical industry Issues mentioned during the PACE roundtable will be summarized along with the Problems identified in this project that can pursued. Finally, the Technical Analysis portion would identify the area proposed to be research in the following semester.

The first section of the report encompasses the top three challenging issues that the project team faced throughout the total duration of the project. The first of which was Coordination of project design with owner equipment. The second major issue was incorporating he $33 million change in scope which is an effect of the first issue mentioned. The third issue was achieving permits on time in order to proceed with the construction tasks as planned.

The second section addresses the methods used to accelerate the schedule whenever it was required. Initially, the critical path of the project is identified followed by stating the major risks to project completion. Then, the key areas that have a potential to accelerate the schedule if needed are stated along with the costs and techniques.

The third section describes the areas of value engineering that were implemented on this project and how they related to the owner. A list of the implemented value engineering work sorted by each trade has been provided in the Appendix. A summary of the total saving that have been attained as a result would be provided in this section in addition to some rejected value engineering ideas.

This portion will talk about the critical industry issues that were mentioned in the PACE sessions. The two sessions are “Assembling an integrated team” and “Integrated decision for high performance retrofit projects”. In addition, the applicability of those sessions will be mentioned in this section along with the main contacts that would help me in applying this to my project.

The last and most important sections are the most important part of this Technical assignment since they will identify the problematic features of this project that could be researched and developed to produce and improved design. The features that could be improved and are discussed in this report are: Coordination & Communication, Delivery system Method, management of the $33 million change in scope, managing acquiring of permits, precast system, excavation and MEP coordination.

The last portion is where the Technical analysis methods are stated and how they can be pursued through a detailed analysis of technical building systems and construction methods. Those analyses are to be pursued and research for next semester. The topics to stated are: IPD application (PACE research), Precast mezzanine (Structural Breadth), Architectural redesign (Fire Protection/Arch Breadth), BIM application. In each of those topics, a problem is mentioned, if there was, along with the benefits and solutions to that problem; in addition to the method of comparison and evaluating of how each analysis would be successful or not.

Constructability Challenges:

The west plant expansion is a project with specific schedule requirements. This is due to the fact that the owner requires that the 1st production date of sellable products be on December 5th. The Schedule, in other words time, is a very important factor when it comes to the process of constructing this plant. As a result, most of the constructability issues , that Turner and the rest of the team had to deal with, were regarding time and scheduling mainly to make sure that work does not stop and the process of completing this project. The top three unique and challenging constructability issues that were faced were all throughout the entire project duration and in the different phases of construction. One of the constructability issues was during the early design phase, another was as a result of a sudden change in scope amidst the construction phase, and the last was all over the project timeline and they are as follows respectively: Coordination of project design with Owner equipment, The $33 Million change in scope, Receiving Permits from the Township, Abu Dhabi DEP and Abu Dhabi Department of Transportation.

Coordination of Project Design with Owner Equipment:

Initially, the design team took the lead of designing the new expansion of the facility. And by designing, I am referring to the Architectural and overall engineering of the building design as well. However, the designers and engineers were not able to finalize their part of the work since the design of the owner's systems and equipment cuts that that will be installed were not available until months after the design team actually required that information to more forward and finalize the design. It was very crucial for the design team to wait for the equipment details as they are the most important aspect in the whole project and the main reason for building this facility; which is for housing and operating the equipment that will eventually produce the goods that is facility is planning on producing.

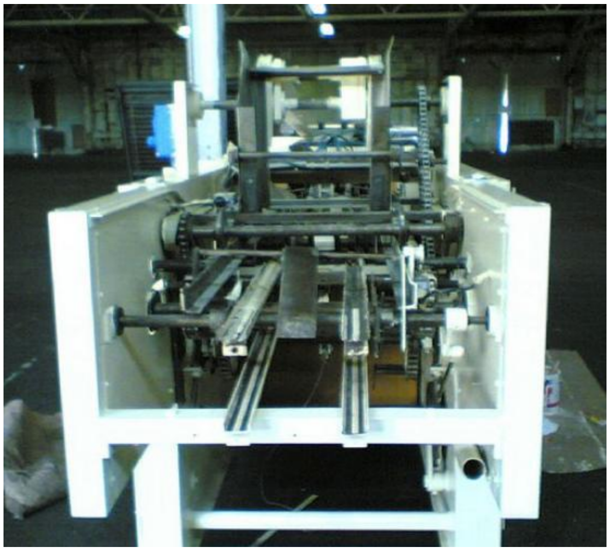

Image 1: Example of Chocolate making Equipment

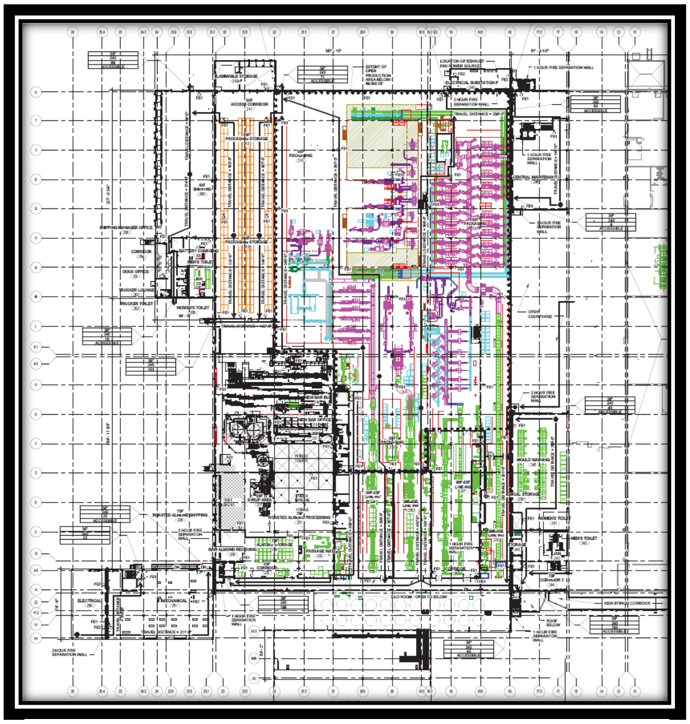

Image 2: First Floor Overall Process Equipment

Image 3: Mezzanine Overall Process Equipment

The site team devised to go around this issue without delaying the design process. They initially created the overall architectural and engineering design. Meanwhile, the team had many discussions with the process team in order to gather as much information regarding the owner's systems and equipment cuts as they became known and available to the team. There were many features and details that affected the design, but it was many regarding clearance requirements for process equipment. The discussions were also conducted on a weekly basis where as soon as any piece of information concerning the equipment that can help get closer to the final design was taken into consideration.

Image 4: Example of Chocolate Factory Equipment

The design team adapted a method in this design where they kept the building's utilities as high as possible and as close to the walls as possible in order to have a flexible approach that they can adapt and implement which would accommodate any of the various and unknown details from the equipment at that time.

As soon as information regarding the process equipment became available from the process team, they were implemented and included them in the weekly coordination meetings. After which they would be the routings would be designed in addition to the equipment details and be implemented on the Turner BIM file.

The $33 Million change in scope

As mentioned in Technical Report 1, the Fuala west plant expansion went through a $33 million change in scope as a result of many factors that design team faced such as the inability to get input from process engineers and plant management which would greatly affect the design, cost and schedule of the project.

One may argue that if the contractor was brought in from the beginning rather than what actually happened which was bring in the contractor at a later time; then they could have assisted with the determination of the issues with the Fuala design. However, as previously stated, only 5 Fuala people were aware of the project and the information could not be developed with the process team until after the vote by the chocolate workers union. The vote occurred in July and the General Contractor Turner was brought on board in July.

The initial design did not accommodate the requirements of the processes to be housed in the facility. And until all information has been provided, the final cost of the project was still unknown. The most recent changes that took the budget from $55 million to the current $85million didn't occur until May 2011.

Incorporating the $33 million in scope growth was the second most challenging issue that was faced in this project. That growth ranged from $15,000 to $500,000 starting at the 60% design continuing to date in addition to continuing to meet owner required interim milestones. The fact that changes had to occur amidst the design process created this major challenge especially that is this is a very expensive project that is also time sensitive in which achieving the project milestones in a timely fashion will be another challenge.

The plan that the team decided proceed to overcome this issue was to award the project on 90% documents in order to allow submittals and coordination to proceed while design was finalized. By awarding the project at 90%, changes could be implemented before the project documents are completely finalized where the GC can provide input. This would reduce the cost since an early change in scope is greatly cheaper and less problematic than last minute or on-site changes.

Having input from the subcontractors and GC regarding any change that may occur is very crucial especially that they will be doing the job in most cases; and from that sense the input that they provide would be different and more beneficial that if it has been done without their input. And so, for changes that that occurred following 100% completion and finalization of design documents, the subcontractors were included in the decision making when it came to design changes in order to assure that the most efficient and effective design was developed and implemented.

As with regard to maintaining schedule and not create any delays, they purchased schedule duration in all subcontracts including meeting with bidders to discuss schedule constraints and how they intend to meet the requirements which included 2nd shift and Saturday work shifts.

Permits:

As a result of the way the project plan was initially conducted, which was through extreme confidentiality for many various reasons, the project was not able to take any official steps in which the project could actually proceed. With that extreme confidentiality comes delay. The West Fuala plant was not able to process any paper work or start anything officially or even get input from the process engineers and plant management. Hence, they faced a lot of issues with regard to that where they had problems receiving Permits from the Township, Abu Dhabi DEP and Abu Dhabi Department of Transportation. This is considered to be the third most challenging constructability issue.

Image 5: Example of a Building Permit

As it is known, receipts of the permits are necessary to begin and continue work onsite. Turner was awarded the project in July 2010. To get designed progressed enough in as short as 3 months to submit documents to governing authorities for review, approval and permit insurance is extremely difficult. One must allow 4 weeks for municipality review/approval and that is without requiring any corrections and/or any variances. Initially, it may not seem that this would be a major issue; however, since permits are required to proceed with any work, most of the work would be halted as a result of a delay in receiving a permit, whether it is the sitework permit, foundation permit, structure/exterior skin and the final permit.

In order to hasten the process and prevent any further or future delays, the design team and Turner Construction Company (TCCo) met continuously with permitting authorities to develop plan to expedite permits. They are receiving permits in phases to meet schedule needs.

Schedule Acceleration Scenarios:

Critical Path of Project Schedule:

The main purpose of the critical path analysis is to be able to understand which tasks are important and should have the priority over other tasks if required. The Critical path of the west plant expansion schedule is a typical one. Turner was awarded the project in July 2010 and needed to start sitework in September 2010, foundations in December, exterior skin in February, and MEP in March to meet the construction Schedule. Those mentioned are the main basic critical tasks that need to complete on time to maintain that the project stays on schedule.

Even though it is an industrial project, the major critical path milestones are the same as mentioned where the basic major stepping stones are as follows: Achieve Permit, Excavation, Mat slabs, Foundation Walls, complete basement, complete precast structure, Roofing & Waterproofing, MEP & Industrial concrete floor, complete steel mezzanine, Interior walls, Landscaping, Substantial Completion

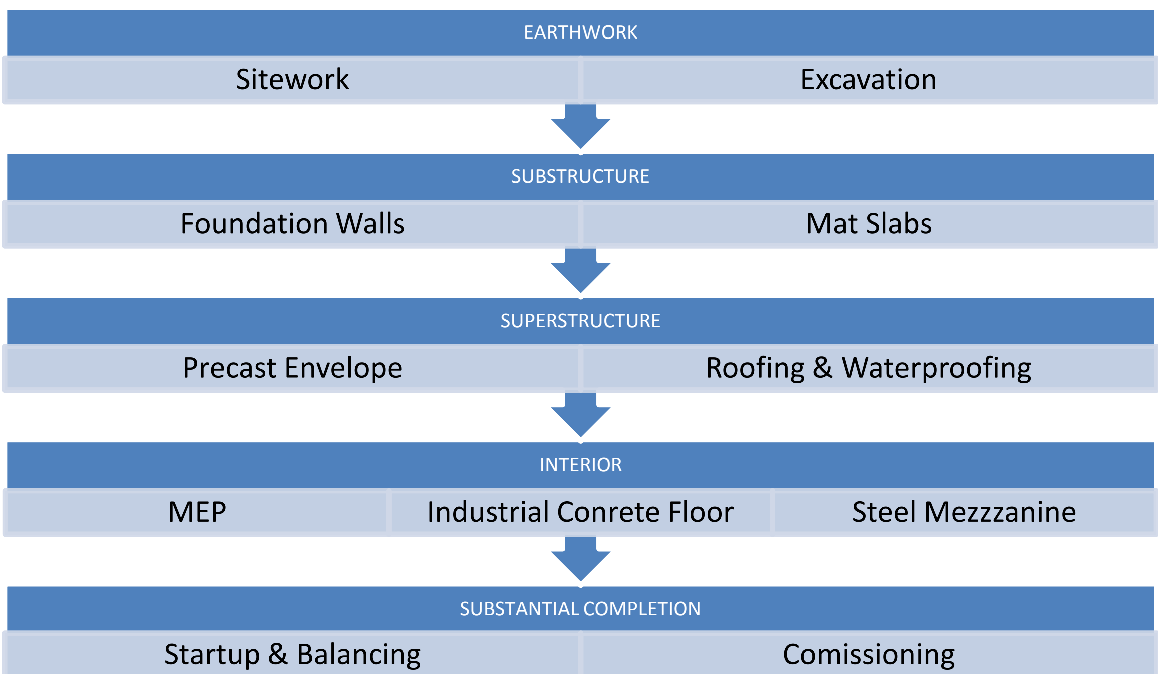

Table 1: Critical path Sequence

Earthwork is the first thing that done after mobilizing into the site. This is scheduled to start on February 14th. Nothing can be done until the Earthwork Phase is completed. In that sense, it must be understood that the entire site need not be excavated before foundation phase can begin;

however, the area where the footing is planned to be placed need to be excavated before that can happen which makes it a critical phase/task. After Earthwork phase is over, the contractor can proceed to work on the substructure phase. The substructure phase consists mainly of creating the building foundations which is mostly basement work as well. Only after the Foundation walls and Mat slabs have been placed that the superstructure phase can begin.

The Superstructure has two main critical tasks: Erecting the precast envelope, which consists of precast walls, precast columns and precast Double Tees; Roofing & Waterproofing, also known as the Building Watertight Phase. With that critical phase completed, the contractor can proceed with the Interior work, which includes mainly the MEP work, Industrial Cast-in-Place Concrete industrial floor, and the steel Mezzanine. Finally, startup and balancing, commissioning and inspections take over the final activities to project substantial completion.

Major Risk to Project Completion:

As one would expect from a major industrial project, the biggest risk to the project completion date is meeting the 1st production date of sellable product on December 5th. And this can only be done by receipt of Temporary Certificate of Occupancy, TCO, prior to December 5th.

Risk has changed as the project progressed; The date of 5th December became the new target and goal to be achieved was just received in September; with that being said, the following could impact the reception date of the TCO:

1. Construction and completion of fire pump house prior to November 21st to meet required flow test date.
2. Receipt of Block elevator certificate of operation. Require operational telephone system which being furnished and installed by THC.
3. Fire alarm system to meet life safety requirements. Is an issue as entire system needs to be operating even though only portion of building will be occupied.
4. Demonstration of mechanical, plumbing and electrical system to Abu Dhabi Township.
5. Township official is on vacation from November 25th to December 2nd which requires that the TCO be received by November 23rd which is 2 weeks prior to Owner required date of December 5th, the targeted date to produce the 1st production of sellable products.

Schedule Acceleration:

Turner had many strategies to catch up on the schedule in case of delays. One of the conservative ways that turner pursued to accelerate the schedule, in case it were required, was to include 2^{nd} days shift operations by the mechanical and plumbing. Additionally, Saturday and Sunday, which are typically off weekend days, were purchased from all subcontractors as no cost make-up days for lost weather. Throughout the project, the electrical subcontractor and ATC contractor worked 2^{nd} shift at no additional cost to the project to meet contractual requirements.

Another issue that required schedule acceleration was with regard to the MEP design. It was an issue for the project as the process teams did not have process loads available as required for the design team. This resulted in the delay of the completion of 100% documents. Recovery project was awarded on 80% complete designs to allow submittals and coordination to start. This would help buying more time in order to catch up with schedule by trying to start early and do the tasks that could be done in order to make-up time.

Additionally, project experienced rain impact in the spring which impacted the installation of the roof. This in turn impacted the installation of insulation on main pipe racks for mechanical systems. As a result, the owner approved of Turner spending $50,000 in contingency to fund premium time only for 2^{nd} shift operations to recover the delay that was caused.

Value Engineering:

As a result of the way the project progressed, which was basically early design without prior knowledge or input from process engineers and negligible coordination and input from Subcontractors or even general contractor, the project ended up with a large change in scope as mentioned earlier. This also resulted in many issues and problems that resulted in many changes in design each costing around $15,000 and up to $500,000 which resulted in the major change in scope of $33 million.

With that being said, a lot of changes occurred when the process engineers eventually provided the designers with the information required in addition to other changes and ideas from the subcontractors and the Construction Manager. The Owner has approved the Value Engineering ideas that have the purpose of reducing cost, increase schedule or simply reducing and/or minimizing inefficiency and unnecessary tasks that could be eliminated without impacting the overall project process, purpose and safety of facility, people and equipment.

The Key areas in which Value Engineering changes were approved and applied are from the architectural, plumbing, electrical and mechanical side. Each of those applied changes has resulted in a good amount of savings for the owner which was summed up to $1.6 million. The breakdown of the savings can be seen in the table below:

VE	Savings
Architectural	$483,894
Plumbing	$238,000
Mechanical	$682,479
Electrical	$206,000
Total Saving	$1,610,373

Table 2: VE Saving Per Trade & Total

A list of the owner approved Value engineering changes can be found in Appendix A

On the other hand, there have a lot been a good amount of value engineering ideas that have been declined from the owner's side ranging from major changes in design which could potentially affect the safety of the surrounding environment or equipment un to minor changes that is not worth the change for the small savings it could produce.

For instance, the suggestion of changing the silo tank insulation from rigid board to spray-on has been declined since the saving that will be obtained it not worth compromising the silos' safety. Another idea that was declined was eliminating control of unit heaters and cabinet unit heaters which are very bad ideas which even if applied would save a maximum of $5,000.

Critical Industry Issues:

Summary of PACE sessions:

Throughout the PACE roundtable meeting, major industry issues have been mentioned by the industry members and by Penn State Professors; the purpose of the PACE meeting is to be discuss and find solutions for the issues that the industry is facing. The solutions to those critical industry issues focus on the balance struck between need to differentiate and innovate in the current market to win work, while still maintaining the core capabilities and practices of the building industry as efficiently as possible. That would be done through examining methods to keep the industry moving forward while integrating new tools, processes, and industry drivers

There were a total number of 6 sessions that have taken place in the PACE roundtable meeting as identified by the PACE advisory board. However, one can only attend a total of 2 sessions only. The two sessions that I have attended were 'Assembling/procuring an integrated team' & 'Integrated decisions for high performance retrofit projects'.

Assembling/procuring an integrated team:

As the name of the topic refers to; the session's main purpose was discussing the benefits and the methods of assembling an integrated team that can enhance the project and take it to another level and the problems or issues that usually arise.

There are many advantages that can be achieved when assembling an integrated team early such as providing input, feedback and suggestions out of experience in order to avoid issues that arise amidst the construction process in which it is much more costly than if discovered or amended earlier. In addition, including the subcontractors or the construction manager early in the design process greatly affects the efficiency and effectiveness when the actual construction of that trade begins.

The usual problem that affects the project when trying to integrate a team officially is that the owner does not understand the important or the benefits that can be reaped from taking such plan into effect; hence, the problem is usually dealing with an uneducated owner that rejects that idea of assembling a team from the beginning in order to avoid 'unnecessary' costs. However, it is the exact opposite since that can help eliminate unnecessary changes that happen later down the line. And so, the goal is educating the owner to achieve great results with regard to technology, innovation and even team collaboration with construction managers and contractors.

As a result of the importance of this matter to the industry, the owner is usually informed about that but for the reasons mentioned above; it is usually rejected to be added to the project as an official requirement. Hence, most assembled teams by the general contractor or construction manager are assembled unofficially without having the approval of the owner since it is very vital for the team in order to achieve a positive outcome of the project.

The most astonishing aspect of applying this idea of assembling an integrated team is the benefits and advantages that can be achieved from such a formation and the disadvantages and costs that can be avoided. However, this has to be formed from the very beginning or as close to the beginning as possible so that the input and feedback is included in the design process as applicable.

Integrated decisions for high performance retrofit projects:

This session's purpose was to identify the best methods and decision that should be made in order to get the highest performance and result from this decision for retrofitting projects.

During the sessions, it was mentioned that measuring the system in retrofitting projects greatly affects the decisions and outcomes on whether the system is worth retrofitting or not. This should happen before the Engineers and Architect comes into the project since sometimes the system is not efficient or worth retrofitting. This is also true since it can avoid the substantial costs of finding that that a specific system is not efficient.

In addition, it is important to know when to work and design alone and when to meet and discuss with the whole team to achieve a better design and take the best decision.

Applicability to current project:

The idea of assembling an integrated team for the West Fuala plant expansion would have been very beneficial for process of constructing the plant. This is very true specifically for this project because of the way the design was developed in the beginning. As mentioned before, there was a team of 5 persons only from the Fuala's Global Engineering Department who developed the project's initial design. Due to the method that was used, the 5 person team that created the original program were not able to get input from the process engineers and plant management which resulted in the $33 million change in scope as a result of having a design that did not accommodate

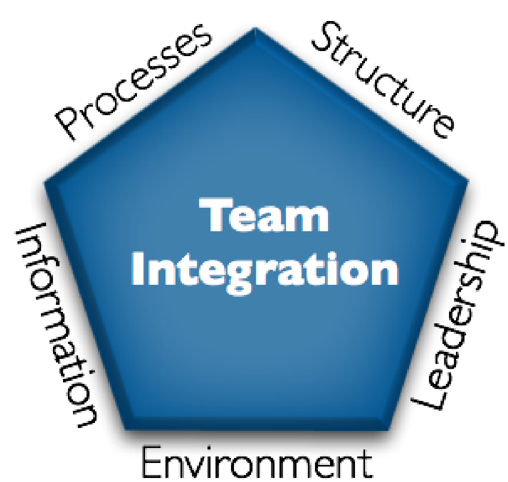

Image 6: Team Integration components

the requirements of the process to be housed in the building.

By assembling an integrated team for this project; the 5 person team would have been able to design with much more precision and knowledge in lieu of what has actually occurred. In addition, having feedback from the general contractor and subcontractors, who will be doing the work that the 5 person team designed, and from the Value engineers will result in some changes in design as required or as necessary. Those changes will reduce the cost of construction in the case of the value engineer. In the case of the changes from the experienced contractors, most of the changed will cause a substantial cost since they are changes that the designers did not have feedback about and are being processed as change orders.

During the 'Focus group' session at the end of the PACE roundtable; I have discussed my ideas with Mr. Bill Moyer, an industry member in PACE from Davis Construction Corporation, where he helped me in arranging and organizing my ideas that were concluded from the PACE sessions. In addition, we discussed generally the breadth and depth ideas that relate to my industrial thesis project. He has suggested a few contacts that could help me in my spring thesis design research and they are:

The Shockey Precast Group

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219 Stine Lane
Winchester, VA 22603
540-667-7700
apayne@shockeyprecast.com

Nitterhouse masonry products, LLC

859 Cleveland Avenue
Chambersburgh, PA 17201
717-267-4500
masonry@nitterhouse.com

Problem Identification:

Identification of Problematic Features:

The west Fuala plant is an industrial project of massive dimensions and systems. The main goal and target of this project is delivery of project on time to owner, to be able to produce the first batch of products on time, in addition to the safety and security of the systems, since faults and modifications would be very costly and time consuming to do after the project has been delivered or even amidst construction. For that reason, any feature that would help reduce schedule time, cost through well studied value engineering and/or safety would be very useful to pursue and research since those are the main columns that the project is restricted and constructed upon.

The following are problematic features or simply methods that could have been improved through a detailed analysis of technical building systems and construction methods which would improve the project as a whole: Coordination and communication, Delivery system method, the merging of the $33 million change in scope to the project, permit managing, precast system, Excavation and MEP coordination.

Coordination & Communication:

First and foremost, the biggest factor that contributed to the major changes that took place in this project was as a result of below minimum communication within the team, specifically between the 5 people team that from Fuala that did the initial design of the entire facility. The team contributed to the biggest change in scope in this project: the $33 million change in scope. As a result of the miscommunication and the super confidentiality, the 5 person team was not able to get input from the process engineers and plant management. This issue hindered the project's development greatly.

Delivery system method:

The other problematic feature that contributed to the issue of communication and coordination was the delivery method that was used. It common for major industrial projects to choose a design-bid-build method as it has been chosen for this project. However, it would have been much better for the owner and the development of the project if the delivery method chosen was different; for instance an Integrated Project Delivery System (IPD).

A Design-Bid-Build specifically requires that the design be completed before it is open for bidders whom will take the roles of building the construction. With such a delivery system the designers do not get input from the construction manager or any of the contractors; such value feedback and input reduces and in many cases prevent such errors from occurring. Hence, this may be a good delivery method in order to look for the best bidders/packagers; however, a delivery that will increase and enhance communication and coordination would have more advantages for the project.

This delivery system does ensure that the project will receive many bids where the best for the project would be chosen (in most cases, the lowest bidder is chosen which is a very bad idea since the best package should be chosen for the good of the project and not the lowest price). This is a major industrial project, not a simple residential project.

Management of the $33 Million change in scope:

Managing the change in scope that occurred was named to be one of the top three constructability challenges by the project manager of this industrial project. Even though they awarded the project on 90% documents ,to allow submittal and coordination to proceed while design was being finalized, and they included the subcontractors in the design ,for changes that occurred following 100% design documents to assure most efficient design; incorporating the $33 million change in scope was a challenge in addition to meeting interim milestone date.

Managing Acquiring of Permits:

One of the major issues that were facing the project was acquiring the projects permits on time in order to proceed with the following task, which in some cases does require acquiring a permit. This problem is also a result of rushing into the project without planning ahead for acquiring the permits and the dates that the project would require to have them. The contractor was brought into the project as soon as it was possible which resulted in this disorder; however, alternate methods of managing and directing this project could have resulted in better outcomes and organization.

Precast System:

The main issue was identifying the size and location of large penetrations prior to 35% design of MEP systems. This information was needed to enable design/fabrication of precast to meet project schedule. For that reason, the design team decided to change rail shed and utility building to structural steel with MEP panel. This was also as a result of acquiring the process team input at a later time than wanted. Hence, the structure of some areas in the project was changes in order to accommodate uncertainty in design, which was a very good adaptive method at the time; however, with a little more coordination and communication, most of these small but costly changes could have been avoided and replaced with better solution that contribute positively to the completion of the project.

Excavation:

Excavation from basement was used as fill for the first floor but until blasting occurred, there was an overall shortage of fill material. Start of blasting required completion of specific erosion and sedimentation controls. An extensive amount of planning was required to assure fill was available to meet project needs. The best way to speed up such a process, where blasting could occur until the completion of erosion and sedimentation control took place, would be by assembling an integrated team which would study all aspects of construction especially and specifically excavation and earthwork requirements. This would assist in planning ahead and staying ahead of the plan by knowing what will happen ahead of time and being able to accommodate for changes in a swift manner since the project team would already have studied the earthwork requirements and the critical path which would make sure that prerequisites have been taken care of to proceed with the work.

MEP coordination:

As mentioned previously, MEP design was an issue for the project as the process teams didn't have process loads available as required for design team. So until that was available, the designing process of the MEP system was an issue. This is a major requirement for the design team where it delayed the completion of the project documents. An increased in communication would have been the solution this problem that delayed a lot of tasks in many phases of the project.

Technical Analysis Methods:

Analysis 1: IPD application – PACE research

The biggest issues that have occurred in this project were mostly related to low communication, interaction and evaluation by all part of the team with a desire to speed the schedule as much as possible in order to achieve the required milestones by the owner. The owner requested that 5 persons from the Fuala's Global Engineering Department start with the initial design of the future facility in a confidential manner at that time long time before it was able to attain the worker's union approval to close the old plant building and open the new facility that Turner will be constructing. As a result of this confidentiality, the designers were not able to get input from process engineers and plant management regarding the requirements of the processes to be housed in the building.

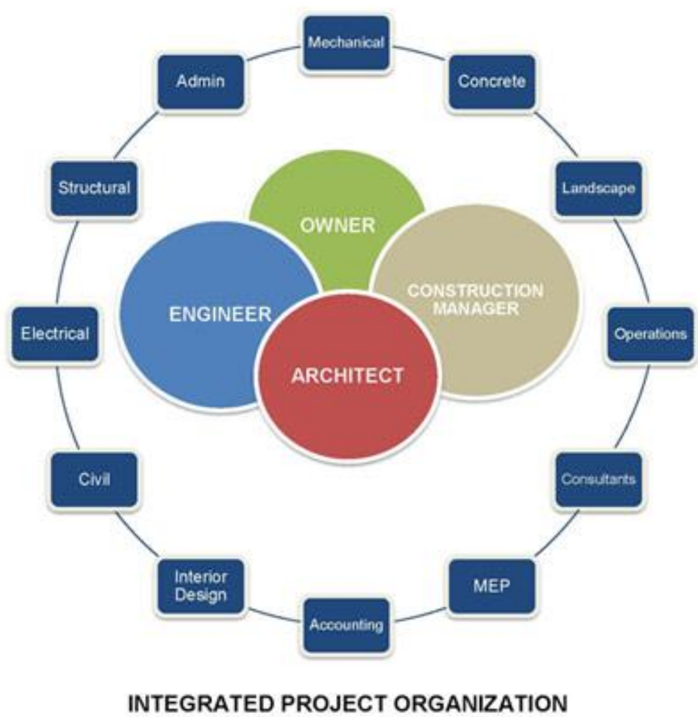

Image 6: Integrated project Delivery

The project was bid as soon as the approval was received; Turner won the bid and came aboard at 90% design documents. As mentioned previously, the project faced a lot of issues with regard to keeping on time, coordinating and getting input and feedback to be able to finalize with the design and construction.

The proposed solution to this entire dilemma would be to change the entire delivery method that has been used to another one in addition to suggesting a change in time frame which would be beneficial in the long term construction of the plant expansion. As for the delivery method, an Integrated Project Delivery (IPD) would be the best and most efficient and effective delivery method for such a project. The plan would be that the designers would hold of the design phase until the approval of the union workers is received. The next step would be to assemble a complete integrated team; this team would be included from the beginning up until the end providing input and feedback to the entire team, starting from the initial meeting with the owner up until the final commissioning.

With that being done, the project would be able to get all the input required to design the process requirements. The $33 million change in scope would have been avoided where the changes would have already been included from the start; moreover, all changes for the project would take place while still in the design phase where it is close to no cost. Coordination would have taken place from the beginning and the details for all systems and structures would have been known and decided upon; for instance, the entire structure could have been chosen to be from precast as was the initial plan. However, the mezzanine and rail shed and a few other areas were changed to a steel structure from precast since the designers where missing the process equipment details.

In order to see if this delivery method would be a good idea; it must be proven that it is much more efficient and effective. The advantage of an IPD over any delivery system is well known and need no elaboration; however, a measure of benefits needs to be decided on to be able to compare the construction management advantages of such a system.

The main measure of whether this method is better than the current would be by comparing the current cost of a design-bid-build (DBB) delivery method with the cost of the project if IPD was chosen. This would be done by taking the current cost of all change orders that took place, which is typically discovered later and results in a larger cost to change, and comparing it to the cost of changing the order in an IPD, which would have been decided at an earlier time than in a DBB. This would provide us with an approximate of the cost that could have been saved if an IPD were done instead. The second method to evaluate the practicality of an IPD over a DBB would be by comparing the change in schedule through all the changes and issues that could have been avoided with an IPD. This would be compared to the schedule duration change that has taken place with the current DBB; this would provide us with an approximate of the schedule time saving that takes place if IPD is chosen.

Analysis 2: Precast Mezzanine - Structural Breadth

If IPD was chosen, many of the changes that occurred would have been avoided. A change in design that could greatly affect the construction management portion of the project would be to change the structural system for the Mezzanine level which is currently a steel structure. The reason why it was chosen to be steel was because the designers did not know about the processes to be housed; hence, they were not able to design the MEP penetrations for a precast mezzanine structure. Since they would not be able to prefabricate a precast mezzanine as a result of the lack of information, a HSS was chosen which does not require prior knowledge of the quantity of penetrations.

Based on the same assumption of having an IPD, all the information required would be already provided. Hence, prefabrication of the entire system would be possible especially with the use of BIM and IPD. In order to check the practicality of this design from a Construction management prospective, some factors have to be compared that include but is not limited to: cost, schedule, logistics, safety and so on.

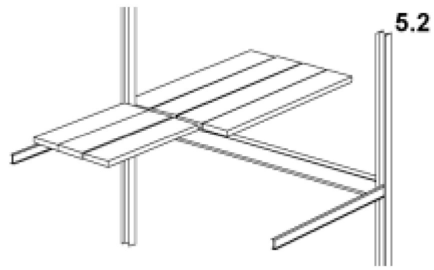

Image 7: Precast Mezzanine Structure

The cost of both systems would be compared and summed up to produce a total for both systems which would be compared. This would include the cost of labor workers, machinery required, material to be bought, transportation of this material, its storage on site and the costs of environmental factors that occur during placing/erecting.

The schedule would be compared to see how this change in structure material would affect the project duration. This would include the duration effect of different labor type, placing time, critical path alteration, efficient of workers which could affect production. This summation of schedule duration would provide a measure of comparison to see which of the two systems would be the better choice.

In addition, a comparison of the difference in safety, logistics and sequence change and how it affects the total project would be prepared. This would help create a measure of assessment between the two systems.

Analysis 3: Redesign - Architectural impact / FP Breadth

In order to deliver the best project according to the owner; one must understand the purpose of this facility and the most important factors/ assets in this new plant expansion. The purpose of this project is to improve the production of this international plant by building a new facility adjacent to the 105 year old plant. Basically to be one of the world's largest and most advanced chocolate-making facilities. With this in mind, one can understand that everything has to be perfectly designed and constructed since this facility will not tolerate any problems that could occur after initial production has started since that will gravely deteriorate the production and sales of this facility which is not an option as mentioned earlier. With that being said, cost of construction should be a factor when considering the best delivery package for the construction of this expansion; however, quality should be the most important factor along with safety since the costs that rise from badly solves issues or low safety practices would be a major cost if it rose later amidst production.

As a result of this logic, the most important thing in this entire facility is the safety of the equipment and the people. As for the people, minimizing and containing the damage would be the goal in case any thing happened to any of the workers. However, in the case of the equipment, if anything goes wrong with any of them, the production of the entire factory could be interrupted temporarily until the problem is solved in addition to time required of ordering and purchasing new equipment. Furthermore, the cost of fabricating and purchasing such custom equipment would be very expensive.

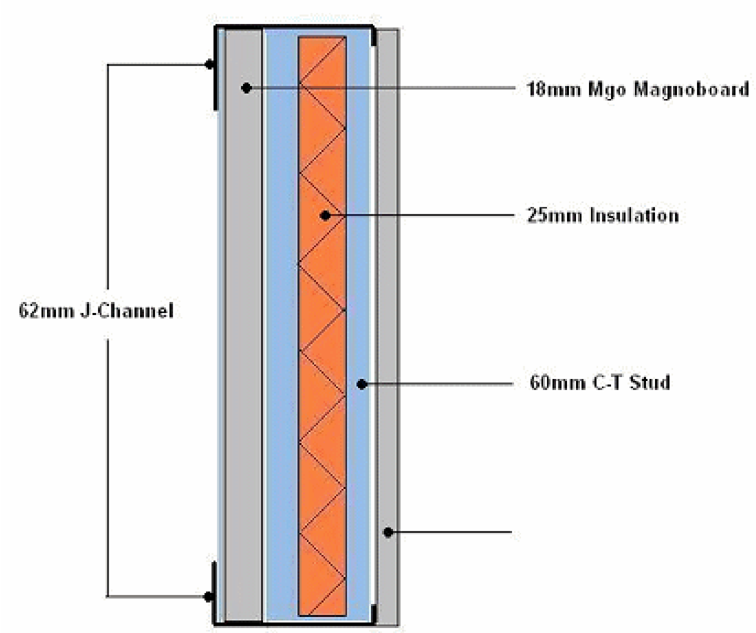

Image 8: Fire Protective Wall Cross-section

The worst case scenario that could occur would be not being able to contain a hazard if it occurs. The most common one would be a fire breakout which if happened would lead to major equipment damage that could flow to all areas of the facility. Hence, the solution proposed would be to redesign the architectural of the facility in order to provide more protection for the equipment by rearranging the areas and creating a number of isolated chambers. Each chamber would not be fully enclosed by basically erect fire retarding and containing walls around each machine that could have that protection added to it.

The measure of success would be done by assessing the cost of construction of the new walls and of the design. Furthermore, the fact that any damage to the equipment cannot be tolerated will dictate whether the cost of the redesign for more safety and less risk is viable or not when compared to the cost of the recovering from a problem in addition to purchasing and ordering new equipment as soon as possible to avoid further losses or the cost of insurance reduction with a safer system.

Analysis 4: BIM application

BIM has been used in this project for two specific reasons only: Clash detection and facilities management purposes. As for clash detection between trades, the BIM use in that sense is mostly used for MEP coordination. The BIM coordinator hosts a meeting where all subcontractors come together to clear any issues that had occurred; the following step would be upon each subcontractor to clear any clashes and then update the BIM file and move on to the next task. The other use of BIM is help the owner coordinate their process equipment. Through the model, the owners would be able to see where there are clearance issues with their equipment. At the end of the project, the model would be turned over to the owner so that they can use it for facilities management purposes.

This project has only used BIM for the most basic reasons during the process of construction which is for clash detection. BIM is not limited to a clash detection tool or a facilities management tool; on the contrary, it is a rich tool that has 21 uses in total including the two uses mentioned earlier. If BIM has been utilized properly to its fullest extent in this project, there would have been major benefits that could have been utilized during all phases of constructing the facility in addition to advantages after the completion of the construction.

This analysis will assess the benefits and advantages of BIM that can attained if it had be used to its fullest extent in this project. The measure of success would be comparing the cost of using BIM and implementing it into the project with the benefits that can be attained.

Appendix A
Value Engineering

Architectural VE #	Description	Savings
4	Delete Blue band	$23,000
7	Delete Wall Removal at Cafeteria	$137,654
8	Leave Existing Cafeteria Finished in Place	$15,000
10	Leave existing Office Vestibule Intact	$8,000
12	Reduce # of showers & fixtures in main locker room	$10,000
13	Reduce # of showers & fixtures in basement locker room	$10,000
14	Change to floor supported toilet partitions	$10,000
18	Delete wall between Chocolate & Corn Syrup Tanks	$17,500
23	Revise 3'-0" high curb thickness from 12' to 6"	$8,500
36	Eliminate Vapor Barrier from Type 2 Roof System	$14,000
37	Eliminate electrically operated dock doors	$17,000
39	THC will furnish/deliver lockers in lieu of furnish new lockers	$135,000
41	Delete person for 6 months for hardware adjustment	$34,000
42	Change 8 line guard rail to 2 line	$44,240
		$483,894

Mechanical VE #	Description	Savings ($)
2	Change Staness Escutcheons to Alternate Material	$5,000
3	Replace Thermometer and Gauges at coils with Pete Plugs at Coils an all FCU, AHU and RTU.	$7,000
6	Delete/ minimize PVC Jacketing on Pipe insulation	$5,000
5	Jamesbury Valves	$522,607
7	Delete color coded pvc jacketing on pipe insulation	$7,000
8	Delete HVAC Support for 3rd Party Commissioning	$20,000
17	Use ¾# 1.5" duct wrap insulation in lieu of rigid board in concealed spaces	$27,000
23	Delete ATC support for 3rd party commissioning	$2,072
24	Eliminate DDC control on Exhaust Fans that Run all the time	$6,681
25	Eliminate RTU points for temperature	$8,836
26	Eliminate RTU points for filter switches	$2,112
27	Alternate technology in lieu of 10" vortex flow meter for control of chillers	$8,171
28	Site Fabrication pump House in lieu of prefabricated	$61,000
		$682,479

Electrical VE #	Description	Savings ($)
1	Allow minimal conductor size to be based on NEC allowable voltage drop in lieu of #10 /#8 awg for lighting	$14,000
2	Allow minimal conductor size to be based on NEC allowable voltage drop in lieu of #10/ #8 awd for power	$12,000
7	Use HPDE cable for site lighting in lieu of conduit	$25,000
8	For Branch Circuit Distribution Combing Circuits in Common Conduit in lieu of Dedicated Circuits	$25,000
10	Reduce number of welding outlet assemblies by half	$25,000
13	Change all grounding conduit to EMT	$22,000
16	Use EMT in lieu of rigid above panels (3’-0”) - substations	$63,000
18	Delete Electrical Support for 3rd Party Commissioning	$20,000
		$206,000

VE	Savings
Architectural	$483,894
Plumbing	$238,000
Mechanical	$682,479
Electrical	$206,000
Total Saving	$1,610,373