Productivity and Safety Analysis for a Storm Water System Improvement Project

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Abstract *— Productivity and safety are key aspects of any company. A decrease in productivity will reduce or eliminate the profit of a project. An increase in productivity will reduce costs. Safety issues in projects will affect productivity directly. This means that an increase in safety will increase productivity and a decrease in safety will decrease productivity respectively. For this study a local construction project was selected and evaluated in those two terms. This research analyzed various studies performed at the site of the project and the design itself. All gathered data, findings and recommendations were given in a final inform to the selected company for their evaluation and future implementation. This study demonstrate the importance of incorporating elaborate safety plans in the designs prior to construction.*

Key Terms *— OSHA, Productivity, PROSHA, Safety.*

INTRODUCTION

The global market changes constantly. New businesses arise and old ones succumb to these continuous transformations. Companies need to adjust their budgets and to seek new ways to perform their daily operations in a more effective and efficient way. The survival of a company shall depend of how competitive their prices are at the moment of bidding for a project or how they manage the activities of any given project. To achieve this competitiveness a company must possess a vast knowledge of techniques, its procedures, materials and external resources among others. Productivity and Safety aspects must be highlighted in order to be competitive now days.

According to The U.S. Department of Commerce productivity is defined as dollars of output per person-hour of labor input. Using this definition, The Department of Commerce reports on U.S. productivity annually [1]. Unfortunate there are no productivity indexes about the construction industry from The U.S. Department of Commerce, U.S. Census Bureau, U.S. Department of Labor or the Bureau of Labor Statistics. There are many ways to increase productivity but not all of them could be apply to a specific project. Each construction project tends to be unique and complex.

Safety issues will affect the productivity on any project and put in jeopardy the most valuable asset that a project will ever had, the labor force. The Occupational Safety & Health Administration know as OSHA is the U.S. Governmental Agency responsible for monitoring and improving all safety aspects of different jobs. Safety requirements changes continuously and improve every day. Nevertheless with all the regulations and new equipment available the construction industry still needs to improve. According to the U.S. Department of Labor the construction industry had 1,016 fatalities in 2008; 879 in 2009; 802 in 2010; 781 in 2011 and a preliminary number of 817 for 2012 [2]. We may add to this numbers workplace injuries and illness. In Puerto Rico the latest report of 2011 showed an increase in fatalities related to construction and extraction to 4 compared to 3 in 2010.

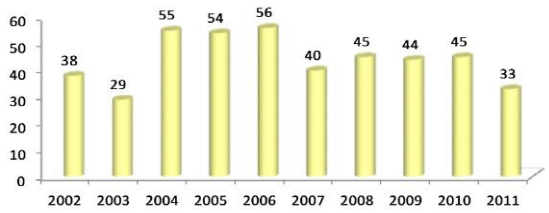

Figure 1
Historic Series of Occupational Death in Puerto Rico

Figure 1 shows all the fatalities related to working in Puerto Rico from 2002 to 2011 [3]. No one should have to die working. This chart shows that there is great opportunities to explore and that improvement is extremely needed.

This research was focus on finding ways to increase the productivity and safety on a storm water system improvement project. The project is currently on the construction bidding process. A local company which identity will remain anonymous for this project was selected for collaboration. An evaluation of the design was performed along its supporting soil and hydrologic and hydraulic studies.

The objective of this study is to better understand the importance of safety in construction projects and how productivity can be improved by it. Also early evaluations and implementations on the designs play a key factor into reducing costs and time of the projects.

The results and observations were given to the owner of the project for reference and evaluation. With the implementation of this recommendations the company can reduce the project costs by eliminating unnecessary change orders, risks to the employees and penalties from regulating agencies. This analysis can contribute in the promotion of safety as worth investing in projects. With better and safety working conditions we promote life and health for employees. This kind of safe environment will eventually be converted in productive man's hours.

LITERATURE REVIEW

Safety

Safety in construction works is well regulated. OSHA is the responsible to assure safe and healthful working conditions for all workers. They set and enforce different standards and provide training, outreach, education and assistance for all employees and employers. The U.S. Congress creates OSHA based on the Occupational Safety and Health Act of 1970 [4]. Puerto Rico OSHA (PROSHA) has adopted their own standards and enforcement policies from an approved state plans.

These are the three fundamental acts that promotes safety and health in Puerto Rico workplaces:

- Act no. 16 of August 5, 1975 known as the Puerto Rico Occupational Safety and Health Act as amended by Act 116 of June 24, 1977, Act No. 32 of July 26, 1991and by Act No. 281 of December 19, 2002.
- Act no. 94 of July 30, 2007 to declare April 28 of each year as the "World Day for Safety and Health at Work".
- Act no. 55 of August 4, 1997 to authorize the Department of Labor to regulate, certify and grant licenses to those persons engaged in the inspection of construction and industrial cranes within the jurisdiction of the Commonwealth of Puerto Rico.

The occupational illnesses affecting construction workers have not been accurately measured, but an educated guess is that construction workers suffer both acute (short-term) and chronic (long-term) illnesses from their exposure to chemicals, dusts, fibers, noise, radiation, vibration, and extreme temperatures [5].

The Code of Federal Regulations is the CFR. OSHA is designated with the Title 29 and the Construction Industry Sector is in Part 1926. This part is subdivided into subparts that range from A to Z. [6]. Puerto Rico OSHA has 18 regulations derived from the CFR.

Productivity

According to the definition of productivity given in the introduction we might infer that there is only one way to increase productivity and is through greater labor effort. That's not true because productivity can increase with better combinations of equipment and labor, the use of better materials, the use of more efficient equipment and tools and improving training of the labor force. There are more ways available to increase productivity in the construction industry [1].

In Puerto Rico construction productivity is not a standardized measure. The lack of productivity data as a result of poor management is often the result of various construction projects. With that scenario it seems to be logic that the construction industry needs more innovation and control. Measuring productivity is important because with an increase in productivity a company will be able to do more with the same or less input which means that they will have an increase in income [7].

About 40% to 60% of the time in a typical construction day process is nonproductive time. This number is too high even knowing that every industry has nonproductive time depending on the nature of the industry, whether conditions and the variability of the physical environment. Labor productivity is the most important component of a project and it is dependent of the materials and equipment. There are many management models to determine the best way to perform a work [1].

Figure 2 shows an example of a typical construction day with respect to productive and nonproductive times. The causes of nonproductive time cannot be blamed all on labor work rules and attitudes, mostly they are the management fault and can be corrected by improved job site management [1].

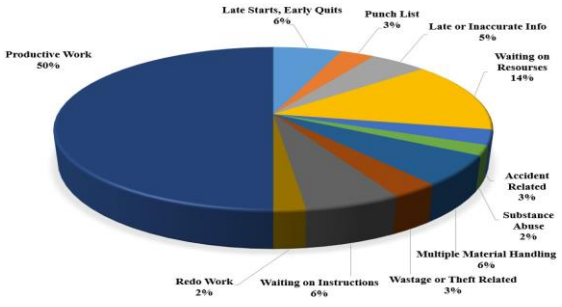

Figure 2
Productive and Nonproductive Time Analysis

Other aspect that affects productivity on construction projects is the use of mechanical equipment like; excavators, dump trucks, rollers, electric generators and water pumps among others. To some projects these equipment's may be optional but for others they are compulsory. This equipment's have high acquisition costs and need routine maintenance and repairs to maintain its value and efficiency [8]. Construction equipment productivity can be improve by a ten point program that include tracking times productive, non-productive and standby, developing accounting process for owned equipment, hourly cost of owning or renting equipment, measuring and managing equipment risk, monitoring variable versus fixed equipment costs, scheduling of equipment, maintenance and repair, location of equipment, selection of equipment and productivity improvement through safety [1].

METHODOLOGY

For this study a local company was selected for collaboration. A real construction project was analyzed for safety and productivity.

The first phase of this research was recollecting safety data like protocols, procedures, notes and recommendations from all gathered documents like site studies and the design delivered by the owner of the project. Also all available project costs were collected and the project delivery system was identified.

The second phase was the evaluation of all the gathered data. Safety aspects were analyzed for compliance with the actual OSHA or PROSHA regulations. Positive and Negative aspects were highlighted and evaluated. Productivity was evaluated in the design with respect to the four preconstruction conditions that adversely affect most projects. The delivery system was evaluated according to its definition and type founded.

The third and final phase was related to the compilation of the results founded in the research of the different evaluations about productivity and safety in the construction project. In those areas were no information was available or found recommendations were made. All the results were presented to the project owner for evaluation and future implementation.

EVALUATION AND RESULTS

According to the first phase the following information was tabulated. Table 1 shows all the

safety related data found in the gathered documents like site studies and the design, all delivered by the owner of the project. Table 2 shows all the costs incurred by the owner in the project up to the time of this research and before the construction bid.

Table 1
Project Safety Data Founded

#	Document	Description
1	Technical Specifications	The contractor shall comply with the applicable provisions of all pertinent codes and regulation.
2	Technical Specifications	Use all means necessary to prevent spread of dust during performance of the work.
3	Technical Specifications	Monitor excavation support and protection systems daily during excavation progress and for as long as excavation remains open.
4	Technical Specifications	Enclose all open excavation with a four foot high temporary fence.
5	Technical Specifications	Design, provide, monitor and maintain an anchored and braced excavation support and protection system capable of resisting soil and hydrostatic pressure and supporting sidewalls of excavations.
6	Technical Specifications	Submit a detailed plan to the Architect showing the design of shoring, bracing, sloping and other provisions to be made for worker protection from the hazards of caving during excavation and trenching.
7	Construction Bid Drawings	The contractor shall recognize and abide by all OSHA excavation safety standards, latest edition, any material, construction methods, or material cost to comply with these laws shall be incidental to the contract.
8	Construction Bid Drawings	Provide barriers, warning lights and other protective devices at all excavations.
9	Construction Bid Drawings	Contractor must stop operation and notify the owner for proper direction if any environmental or health related contaminate is encountered during excavation.
10	Geotechnical Evaluation	Therefore, we have evaluated the safest geometry that shall be imparted to the resulting excavation sloped walls.
11	Geotechnical Evaluation	Differing soil conditions between borings locations cannot be discarded at all, therefore localized surface slides, can take place and endanger the life of working personnel.
12	Geotechnical Evaluation	Excavated material that is stock piled at the top of the slide slopes represents an increased load thus can generate a slope failure.

Table 2
Incurred Project Costs

#	Description	Cost
1	Hydrologic and Hydraulic Study	$ 14,500.00
2	Hydrologic and H Study Amendment 1	$ 2,800.00
3	Horizontal and Vertical As Built Survey	$ 12,000.00
4	Survey Cross Sections	$ 18,000.00
5	Initial Geological Field Visit and Memorandum 1	$ 700.00
6	Geotechnical Evaluation	$ 12,395.00
7	Design Proposal	$ 45,095.00
8	Change Order 1 New Design Alternative	$ 23,974.00

Regarding the delivery system of the project it was found that the owner likes to use the general contracting process. This is the traditionally construction project that is undertaken as a three party process involving the project owner, the project designer (architect or engineer) and the contractor team led by a general contractor [1]. See the structure in Figure 3.

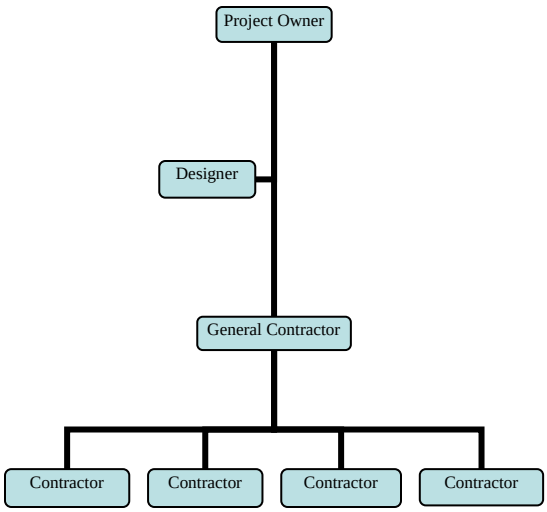

Figure 3
General Contracting Process Structure

For the second phase the following evaluations were made. All the safety notes founded on Table 1 complies with OSHA Regulations. The safety notes on the technical specifications that complies are number one with the 29 CFR 1926 P related to the overall safety in excavations, number two with the 29 CFR 1926 D .55 concerning environmental controls of gases, vapors, fumes, dusts and mists, number three, five and six with the 29 CFR 1926 P .651 (k) (1) about inspection of excavation requirements and number four with the 29 CFR 1926 M .502 (b) (1) regarding the criteria and practices of fall protection systems. The safety notes related with the construction bid drawings that complies are number seven with the 29 CFR 1926 P related to the overall safety in excavations, number eight with the 29 CFR 1926 M .502 regarding the criteria and practices of fall protection systems and number nine with the 29 CFR 1926 Z about toxic and hazardous substances. The safety notes about the geotechnical evaluation that complies are number ten with the 29 CFR 1926 P .652 (b) (4) concerning the requirements for protective systems designed by a registered professional engineer, number eleven with the 29 CFR 1926 P .651 (j) related to the protection of employees from loose rock or soil and 29 CFR 1926 P .651 (k) about inspection of excavation requirements and number twelve with the 29 CFR 1926 P .651 (j) (2) regarding to the protection of employees from loose rock or soil.

Analyzing the safety aspects in the technical specifications, construction bid drawings, the geotechnical evaluation and the hydrologic and hydraulic study we found that little or no instructions at all were presented for this project. Regarding the complexity of this project there is no safety plan implemented. In many notes a general clause was used referring to comply with the applicable regulations and standards. Only in some parts were details about fence high, barriers, warning lights, instructions to the contractor in case of environmental and health problems, differing soil conditions and material stock piling on top of the slide slopes. Other notes delegates some responsibilities to the contractor like submitting designs of shoring, bracing, sloping provisions and to monitor the excavation.

The first preconstruction condition that affect productivity is the lack of control of the schedules activities during that phase [1]. In this project no schedule was found for the preconstruction phase. This project started in the month of July 2011 with the collapse of two old drainage concrete pipes crossing the site. Almost three years have passed since those events and the reconstruction of the areas and the improvements to the pluvial system have not yet started. Various works have been done during that time like unclogging the pipes, some land refill, hydrologic and hydraulic studies, land surveys, geological studies and the construction design. Still to happen the construction itself. All this activities performed without a proper schedule. The owner was responsible too for time delays related to budget issues and decision making related to the selection of the alternatives presented. Time was wasted in this project and time affects productivity. Even change orders and amendments were made during this preconstruction phase which increase the cost of the project for $26,774.00 about 34% of the total cost.

The second preconstruction condition is about disputes over inadequate drawings and specifications that could create interpretation

problems [1]. It was found on the technical specifications and the design drawings some general notes with vague terms like “Use all means necessary” that could create misunderstandings in the construction phase. Even many errors appear related to information about other clients and jobs not related to this project that should not be presented. Various notes and detail drawings were unnecessary because they didn’t relate to the scope of work to be performed. The specifications and the design drawings will be part of the bid documents and henceforth will be part of the contract documents.

The third preconstruction condition relates to problems associated with a design that fails to take into account efficient and productive construction methods [1]. For this project the designer was not involved in the construction methods. In few notes recommended various options to be considered by the contractor. Only in one area delimited the use of laser grading methods to assure flat and level aggregate base course placement.

The fourth and final preconstruction condition is related to cost-ineffective design that does not yield optimal design value and thus lessens productivity [1]. Any technique for optimizing costs or a value engineering evaluation was not found in this construction project. Even though various alternatives were presented to the owner in terms to reduce the construction costs. Regardless that the selected option was not the most expensive, in the hydrologic and hydraulic study a long term maintenance plan was strongly recommended to avoid reduction of the capacity of the system or even clogging of the same. Such maintenance plan was not incorporated in the design.

The project owner prefers to use the general contracting process delivery system for their projects commonly known as the Design Bid Build. This system is used by many construction projects for many decades and the process is well studied, documented and tested in law. It is characterized by construction guaranties and a promise of results [1]. Nevertheless there are other alternatives for the delivery system like the Design Build, CM and a recently new Integrated Project Delivery. Other variations of this three and the Design Bid Build are available too depending on the needs of the project.

The Design Bid Build have some disadvantages and some of them were found on this project. The first one is that the overall process is long compared with other methods and this project has been in development since July 2011 and the construction bid has not been placed. The costs of the construction is unknown until the bids are delivered. Because the construction bidding could not take place until the design and specifications were completed there is a risk that the bids may exceed the owner's budget and therefore require that the owner either redesign, delay or abandon the project. This delivery system tends to increase the probability to develop change orders and this project has already one change order in the design and one amendment in the hydrologic and hydraulic study that increased the project cost by $26,774.00 and the construction have not started. This general contracting process requires that the owner paid upfront the design and any related initial studies before the construction begins which make some economic pressure on the owner. For this project it was a determine factor because the owner didn’t have in the budget all the necessary money to perform the hydrologic and hydraulic study, the surveys, the geological study, the design and the construction all at once. This caused a delay in the works and affected the productivity of the project. All the work performed were divided thru the owners budgets of the years 2011, 2012, 2013 and 2014.

Comparing the advantages and disadvantages of the delivery system used in this project with the advantages and disadvantages of the other three principal systems with the owner needs, limitations and methods it shall be said that the selected method is still the best option for this project with some recommendations. The Design Build option will not work for this project because the owner needs to be involve and control all the steps of the design and to manage directly the contracts involved. The Integrated Project Delivery system

couldn't be an option because the owner is very traditional, the process presents structural and contractual complexity and the system needs to be tested in laws to be reliable. The CM is the system that could had been merged with the actual project system in order to achieve a more complete design with more construction perspective and safety development.

A compendium of the results and recommendations obtained in this research was made for the third phase as follows. All the safety notes founded on the gathered documents complied with OSHA regulations which is good but not enough, a safety plan wasn't implemented as indicated in the 29 CFR 1926 C .35 (a). This section of the OSHA regulations explain in detail all the necessary aspects of the plan. The lack of specific details and instructions related to safety in the designs may become expensive and dangerous during the construction phase. Omissions, errors, the use of old regulations, waste of time, misdirection, productivity loss, misinterpretation and disputes could arise without a proper guidance in safety and the worst of all, a fatality could happen.

Productivity in this project was affected by the absence of a proper schedule of preconstruction activities that causes time loss. The more this project is delay, the more the owner lose profit form the full and proper use of the facility. Another aspect that affected productivity was the errors founded in the technical specifications and drawings which include information of another project, vague notes and instructions and unnecessary details not related to this project. The faults founded presents a serious potential for disputes and waste of time with clarifications and could lead to constructions errors and change orders that will reduce the productivity and increase the costs of the project.

The design didn't include any construction methods, only made a brief recommendation for a specific area. This project will require a lot of earth movement and with that the use of heavy equipment. Since no method is presented in the design it's recommended to take precautions to avoid productivity loss during the earth movement operations. The productivity improvement ten point program mentioned in the definition of productivity will do the job. The not involvement of the designer in the construction methods simplify the designers responsibility in the project and even the design costs. But could put in jeopardy the overall productivity of the construction phase leaving the responsibility to the contractor who might or not might know the best and efficient ways to perform the work. Disputes may arise as nonproductive time, which may cause costs overruns.

This project could had receive many benefits if the design were evaluated by a value engineering technique. Besides the few alternatives presented for costs reduction various changes were made on the studies that increase considerably the project cost on the preconstruction phase. Another cost ineffective aspect that this project presented on the design was the absence of the recommended long maintenance plan. This plan will increase the cost of the project in the operation phase and affect negatively the productivity of the system if not considered. If the owner were to decide not to implement the maintenance plan to reduce costs or implement just part of it, the overall project and investment will be put in risk.

The delivery system for this project was validated to be the best option in terms of the structure which is common and well understand and because the owner needed to maintain certain control and participation in the design and management of the preconstruction phase. Although some deficiencies were found in terms of time management, scheduling, budget and change orders. In future projects with the aid of a construction manager all of them could be minimized or eliminated reducing the nonproductive time in the preconstruction phase which will improve the productivity. The CM could had helped in the development of preconstruction schedules, drawings, specifications and procurement. Besides the implementation of detailed construction methods, the safety and

maintenance plan in the design. Even help and guide the owner to avoid unnecessary delays and change orders that reduce the productivity and increase the costs.

CONCLUSION

Safety and productivity are aspects that needs to be compulsory involve and developed in modern construction projects in order to reduce costs and time. But somehow they manage to pass unseen thru the eyes of the project owners and designers. Safety plays a big role during the construction phase but the life and health of the persons working in the early stages of the project are important too and need to be protected. Protection will be transformed into confidence and confidence into productivity of the employees. That's why it is imperative to invest in safety and the reimbursement of such investment will be more and worth. In this project safety will be increased by the implementation of elaborate safety plans according to the law. On the other side productivity in this project could be increased not only by safety, but thru the reduction of nonproductive times associated to the absence of schedules, budget deficit and poor design. Prevention and early implementation are key factors in the reduction of nonproductive times. A construction manager could had help in this project to reduce those times and enhance the overall design. A direct reduction of nonproductive times will increase the productivity of the project and hence increase its profit.

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