Evaluating Productivity in a Structural Steel Installation Construction Project in Puerto Rico

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Abstract *— The research project was focused on the evaluation of the productivity in a structural steel installation project in Puerto Rico. The two projects evaluated have similar site conditions and safety requirements. The installation process of the respective projects is different because the erection activity used different employee man-power whether subcontracted or in house. It was demonstrated in this research that all factors have to be considered because for a project to be productive the adequate use and analysis can mean the difference between a profitable or non-profitable project. For this research the structural steel industry was evaluated with the proper use of productivity data analysis from the accounting process and documentation of two projects respectively.*

Key Terms *— Productivity, Profit Margin, Total Quality Management, Subcontractor.*

INTRODUCTION

The structural steel construction industry is separated in three main categories: material, fabrication and installation. The construction industry has had many changes in the past years due to the change of global expectations, its focus on cost reduction, on environmental challenges and on the need for profit reduction in order to be competitive. This has created awareness to the fact that poor performance affects the project owners, the designer, and the whole construction team. There is some indication that productivity decreases for many reasons that are unique for this industry such as unpredictable weather and the fact that nearly every project is singular in some aspects of its design and construction. As Mr. James D. Whiteside, II, PE would express, "In a perfect world, perfect productivity (1.0) would be accomplished in a 40-hour work week, with everyone taking all of their holidays and vacation days as planned. All of the engineering drawings would be 100 percent complete, there would be no delays of any kind, everyone would work safely, everything would fit perfectly the first time, the weather would be 70 degrees Fahrenheit, and there would be no litigation at the end of the project" [3]. As the industry is investment-driven, it is subject to the economic upturns and downturns; during the recessions of the mid 1980's and the early 1990's, there were significant downturns.

However, in the late 1990's, there was a marked swing in the opposite direction. Structural steel enhances construction productivity because of its shop fabrication while maintaining tight construction tolerances. Field placed material will always lag behind the productivity curve. Productivity improvement in the construction field will occur not in labor based field activities, but in shop based technology enhancements. The installation activity cannot be improved but the fabrication activity can be accelerated with the use of technology. Rapid erection in all seasons with close tolerances being maintained for integration with other building systems and minimal construction site waste is achievable only with structural steel. Today, when competing framing systems are evaluated for projects using comparable, current cost data, structural steel remains the cost leader for the majority of construction projects. Comparative studies indicate that a structural steel framing system including decking and fire protection will typically cost 5% to

7% less than a concrete framing system on a national basis.

Research Description

This research is based on a direct comparison of documentation (accounting books, bid documents, etc.) of a structural steel installation project in Puerto Rico. Productivity was evaluated in the following areas: personnel, equipment and fabrication. This is to determine areas of improvement, to increase productivity for future projects in order to increase profit margin, maintain Total Quality Management (TQM) and be competitive in the industry.

Research Objectives

This analysis will help understand the importance of monitoring the productivity for a steel installation construction project and correctly evaluating a project in the biding process. It will also demonstrate the importance of communicating how, from the different company departments of the company (Drafting, Estimate, Production, etc.) that are involved in the construction process, factors that affect productivity can be reduced or eliminated.

Research Contributions

The calculation or estimation of the impact of labor productivity is one of the most contentious topics in the construction industry. Disputes related to labor productivity often lead to dispute resolution forums such as mediation, arbitration, and/or litigation because labor productivity losses are often difficult to distinguish in real life. Additionally, labor productivity rates and other related data are often not tracked on construction projects with any degree of precision. As a result, substantiating a cause-and-effect relationship between project disruption issues and resulting labor productivity losses and establishing entitlement to recovery for lost labor productivity often requires analysis by a qualified construction labor productivity expert. In the construction industry in Puerto Rico documented productivity analysis is almost non-existent and in the structural steel industry this has never been documented. This research aims to expose the need for proper documentation and implimentation of productivity in the construction industry in Puerto Rico using the steel industry as a example.

LITERARURE REVIEW

For a better understanding of this reseach we have to review the main concepts.

Productivity Review

Productivity analysis refers to the process of differentiating the actual data over the estimated data (output and input measurement) and calculating the difference. Productivity — Is a measure of the efficiency of production. Productivity is a ratio of what is produced to what is required to produce it. Usually this ratio is in the form of an average, expressing the total output divided by the total input.

Productivity loss, therefore, is experienced when a contractor is not accomplishing its anticipated achievable or planned rate of production and is best described as a contractor producing less than its planned output per work hour of input. Thus, the contractor is expending more effort per unit of production than originally planned. The result is a loss of money for a contractor. Therefore, a challenging aspect of construction cost control is measuring and tracking work hours and production in sufficient detail to allow analysis of the data in order to determine the root cause(s) of poor labor productivity, should it occur [3].

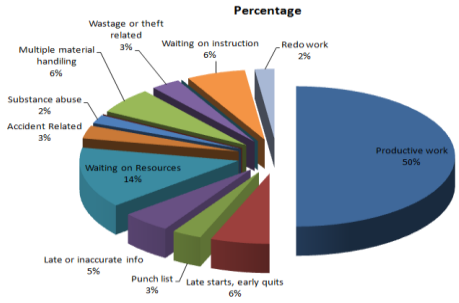

Figure 1
Analysis of Productive and Non-Productive Time [4]

In Puerto Rico, construction has a different distribution of worker productivity. This can fluctuate based on the season of the year due to wheather conditions and cultural activities (See figure 2). When evaluating productivity these are some of the factors that have to be considered. (See Figure 1)

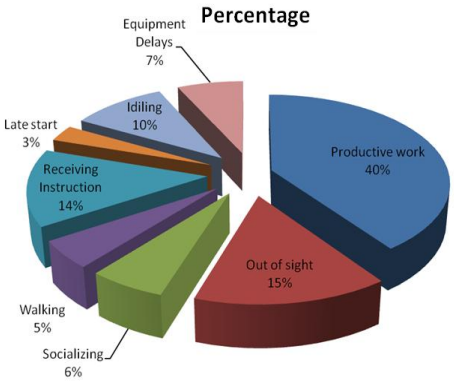

Figure 2.
Total Workers Time Distribution in Puerto Rico

Steel Review

When founded in 1901, United States Steel Corporation was the largest business enterprise ever launched, with an authorized capitalization of $1.4 billion. Throughout the years, U.S. Steel responded to changing economic conditions and new market opportunities through diversification and periodic restructuring. Today, over a century after its founding, U.S. Steel remains the largest integrated steel producer headquartered in the United States.

U.S. Steel had its origins in the dealings of some of America's most legendary businessmen, including Andrew Carnegie, J.P. Morgan, and Charles Schwab. However, its principal architect was Elbert H. Gary, who also became U.S. Steel's first chairman. At the turn of the century, a group headed by Gary and Morgan bought Carnegie's steel company and combined it with their holdings in the Federal Steel Company. These two companies became the nucleus of U.S. Steel, which also included American Steel & Wire Co., National Tube Company, American Tin Plate Co., American Steel Hoop Co., and American Sheet Steel Co. In its first full year of operation, U.S. Steel made 67 percent of all the steel produced in the United States [6].

In the decades that followed, the corporation consolidated its various steelmaking and raw material subsidiaries and divisions through a series of reorganizations. Many of the corporation's divisions were related to or grew out of the company's original steel operations. Significant diversification and restructuring actions occurred in the 1980's, particularly in 1982, when the corporation became involved in the energy industry with its acquisition of Marathon Oil Company. In early 1986, the corporation expanded its energy business when it acquired Texas Oil & Gas Corp.

In late 1986, recognizing the fact that it had become a vastly different corporation, United States Steel Corporation changed its name to USX Corporation, with principal operating units involved in energy, steel and diversified businesses.

The 1980's also brought significant changes to the corporation's steel operations. In response to economic changes in the steel industry, the corporation reduced its domestic raw steel production capability through a number of restructurings. In addition, the corporation entered into several steel joint ventures with both domestic and foreign partners.

At the same time, many of the units among the corporation's diversified businesses were sold or combined into joint venture enterprises. These included chemicals and agri-chemicals businesses, an oil field supply business, domestic transportation subsidiaries and raw materials properties worldwide.

Turning to the financial structure of the corporation, in 1991, shareholders approved a proposal to change the capitalization of the corporation. A new class of common stock was issued, USX-U.S. Steel Group Common Stock (NYSE: X), to reflect the performance of the corporation's steel and diversified businesses. USX Corporation common stock was changed into USX-Marathon Group Common Stock (NYSE: MRO) to reflect the energy side of the business.

In 2007, U.S. Steel made two more value-building acquisitions. The first was the purchase of Dallas, Texas-based welded tubular products maker Lone Star Technologies, Inc. and its related companies in June. The deal made U.S. Steel the largest tubular goods producer in North America, with total annual capability of 2.8 million net tons. On Oct. 31, 2007, U.S. Steel increased its flat-rolled products capacity by acquiring Canada's Stelco Inc., which it renamed U.S. Steel Canada. The additional 4.9 million net tons of raw steelmaking capability at the U.S. Steel Canada facilities raised U. S. Steel's total capability to 31.7 million net tons, the fifth highest total among steelmakers worldwide.

Today, U.S. Steel remains proud of its past, but is focused on its future. As a leader in the increasingly competitive global steel industry, United States Steel Corporation is dedicated to delivering high-quality products to their customers and building value for all of their stakeholders

Founded in 1961 by José Alonso and Laureno Carus, ALONSO & CARUS Iron Works, Inc., has participated in the construction of hundreds of demanding and challenging projects, including many landmarks of Puerto Rico and the Caribbean region, that showcase the superior capabilities of steel. As the largest integrated structural steel and tank fabricator in Puerto Rico, A&C provides a full range of design, engineering, fabrication and erection services through an innovative, responsive and customer focused organization.

In 1966, José M. Junco anticipated that the economic development of Puerto Rico would grow for years to come. Junco wanted to contribute effectively to this development by focusing on the distribution of metal products, steel and pipe. With this goal and purpose in mind, Junco organized JUNCO STEEL CORP., in the Monacillos Ward in San Juan, Puerto Rico.

After his death in 1999, "Don Pepe" left a legacy to his successors: a desire to excel, hard work, courage, the quality of life and service for all. These attitudes and virtues helped him greatly to succeed in business [5].

Upon obtaining his Mechanical Engineering Degree and working for many years in the construction industry in Puerto Rico, Jose Aguayo founded Structural Steel Works, Inc. (SSW) in 1968. Like many U.S. fabricators, Structural Steel Works, Inc. started in the steel trade as a job shop primarily fabricating miscellaneous steel and erecting small structures.

In subsequent years the company's growth paralleled the increasing demand for steel as a building material on the Island where the market was previously dominated by reinforced concrete. By the early 1980's Structural Steel Works Inc., had established itself as one of the most distingushed steel contractors in Puerto Rico. It's massive and "State of the Art", 120,000-square foot manufacturing facility sets the standard for quality of steel fabrication, installation, and sales in Puerto Rico.

Structural steel is the most recycled material on our planet – today's structural steel is made of 88% recycled product, is fully recyclable in the future and can be reused without further processing. The carbon footprint of structural steel has been reduced by 47% since 1990. Energy used in the production of structural steel has been reduced by 9% in the past 10 years and over 30% in the past three decades [1].

METHODOLOGY

This research analyzed and compared two (2) construction projects under similar condition of safety limitations, equipment requirements and fabrication.

In project 19017 the installation process was performed by in-house employees and supervision. Project 19024, on the other hand, was performed by a subcontracted installation company. This analysis was based on the different impact factors that affect productivity in a steel installation project.

For this research the following four (4) steps were completed for the analysis:

1. Collect productivity and cost data

Use the accounting process to collect productivity and cost data from the past jobs. Separate the cost information in different items: payroll, equipment, fabrication, overhead, and material. This is to evaluate these areas independently and indentify specific improvement areas.

2. Evaluate the information using the Productivity model

Use the accounting process to collect productivity and cost data from the past jobs. The information that is collected from the accounting records can be distributed in many categories, for example: fabrication can be separated in payroll of welders or chauffeurs and material could be ordered from mills, but it could also be used from the same material that is in stock. These items have to be evaluated and quantified to have a correct evaluation of the cost of every item. After the information is correctly segregated in their respective departments then final costs can be established for every project respectively.

The bid information has to be separated by departments to have a direct comparison by department. For this particular research the information was separated in different departments, however only equipment, personal and overall profit will be evaluated for productivity [2].

$$\text{Productivity} = \frac{\text{Output (units completed)}}{\text{Input (work or equipment hours)}}$$

$$\text{Productivity Factor} = \frac{\text{Actual Productivity}}{\text{Baseline or Planned Productivity}}$$

Figure 3
Productivity Equations

The percentages of the different activities independently, provide information to evaluate productivity and efficiency by activity.

3. Document results for future reference

This final and most important step is carried out to document the result of constant productivity evaluation in order to determine areas for improvement. The construction industry in Puerto Rico lacks of Research and Development (R&D) in productivity areas. This will provide a base line to evaluate productivity in the construction industry.

RESULTS AND DISCUSSION

This section discusses the results of the research in the different steps.

Collect productivity and cost data

The accounting department provided the following information for the two (2) projects respectively. They have been labeled job 19017 and job 19024. Job 19017 has the particularity that the erection process was done by in-house employees and job 19024 was done by a subcontracted group of employees. They had the same project manager, fabrication facilities, and material suppliers. The following information was supplied (See Table 1):

Table 1.
Actual Cost of Construction Projects

Actual Project Cost		
Items	19017	19024
Equipment	$ 36,195.00	$ 45,995.00
Payroll	$ 61,349.77	$ 43,000.00
Material	$ 260,832.00	$ 108,489.00
Fabrication	$ 217,360.00	$ 90,408.00
Drawing	$ 8,694.40	$ 6,000.00
Actual Total Cost	$ 584,431.17	$ 293,892.00

The estimated cost by activity that was presented in the bid documents is summarized in Table 2.

Table 2.
Estimated Cost of Construction Projects

Estimated Project Cost		
Items	19017	19024
Equipment	$ 73,272.50	$ 26,800.00
Payroll	$ 73,272.50	$ 67,200.00
Material	$ 260,832.00	$ 112,361.00
Fabrication	$ 153,980.00	$ 112,361.00
Drawing	$ 13,172.60	$ 3,616.00
Others	$ 84,100.40	$ 37,752.00
Actual Total Cost	$ 658,630.00	$ 360,090.00

Evaluate the information using the scientifically based Productivity standards

Installation Evaluation: The Gross Profit Margin of the installation process was evaluated using the productivity equations in Figure 3.

The information was separated by the different components; installation, equipment and overall project income (See Table 3).

Table 3
Gross Profit Margin of the Installation Process

Job#	Estimated Installation Cost	Actual Equipment Cost	Actual Payroll Cost	Actual Installation Cost	Gross Profit Margin
19017	$146,545.00	$ 36,195.00	$ 61,349.77	$ 97,544.77	33.44%
19024	$ 94,000.00	$ 45,995.00	$ 43,000.00	$ 88,995.00	5.32%

Based on the projects results in the installation process both projects were under the estimated cost for this activity. In project 19017 the Gross Profit Margin was 33.44% compared to Project 19024 where the Gross Profit Margin was 5.32%. This information can indicate the following:

- That the estimated cost of equipment and labor was correctly estimated and has a margin of profit or,
- Labor and equipment where productive managed in the installation process.

The individual evaluation of the two principal components of this activity gives more information on areas of improvement and productivity increases. This information was evaluated and summarized in Table 4.

Equipment analysis:

Table 4
Equipment Activity Profit Evaluation

Job#	Estimated Equipment Cost	Actual Equipment Cost	Equipment Profit %
19017	$ 48,843.45	$ 36,195.00	25.90%
19024	$ 26,800.00	$ 45,995.00	-71.62%

Based on the project results in the installation process in project 19017 the equipment profit was 25.90% compared to project 19024 where the equipment profit was -71.62%, this information indicates the following:

- That the estimated cost of equipment for Project 19024 was under the cost of equipment that was used in the installation process. The negative margin indicates that all the overhead and profit in this activity was consumed. To manage this situation the estimated equipment cost has to be changed for more economical equipment. This change of equipment can affect the schedule of the project or the efficiency of the employees doing the activity.
- In Project 19017 the equipment where managed correctly. Project 19017 had a higher productivity than Project 19024 in the use of equipment.

One of the main components of the installation process is the payroll activity. This information was evaluated and summarized in Table 5.

Table 5
Employees Activity Profit Evaluation

Job#	Estimated Payroll Cost	Actual Payroll Cost	Payroll Profit %
19017	$ 97,701.55	$ 61,349.77	37.21%
19024	$ 67,200.00	$ 43,000.00	36.01%

Payroll Analysis: Based on the projects results in the installation process in Project 19017 the payroll profit was 37.21% compared to Project 19024 where the payroll profit was 36.01%. This information is demonstrated in Table 5. This information indicates the following:

- That the estimated cost of payroll was correctly estimated and has a margin of profit. Project 19017 payroll profit is higher than project 19024. Project 19024 man-power was subcontracted for a fixed price. Project 19017 employees were in-house employees. In some cases the use of in-house employees is more efficient depending on the following items:
- Project location: costs have to be evaluated to determine if providing transportation, housing, and other provision to in-house employees is cost efficient.
- Availability of employees: If all employees are located in other projects it will be necessary to subcontract the installation.

- Schedule: Project requesting high quantity of employees in acceleration to reduce time lines in the schedule can require the use of a subcontractor.
- Total Quality Management: The use of subcontracted work force can cause a quality reduction. This quality is affected because the subcontractor main interest is to complete the project fast to reduce cost and increase their profit margin. If this situation is not addressed re-work, schedule impact, client discomfort, and overhead can be affected. Problem with quality can reduce client retention rate for future projects.

Table 6
Gross Profit Margin of the Projects

Job #	Contract Amount	Estimated Cost	Actual Cost	Gross Profit Margin
19017	$ 658,630.00	$ 658,630.00	$ 584,431.17	11.27%
19024	$ 359,995.00	$ 360,090.00	$ 293,892.00	18.36%

Erection Analysis: The overall original contract amount compared to the actual construction cost demonstrates a profit margin in Project 19017 of 11.27% and for Project 19024 of 18.36%. Based on this information both projects were managed correctly and generated profit for the company (See Table 6).

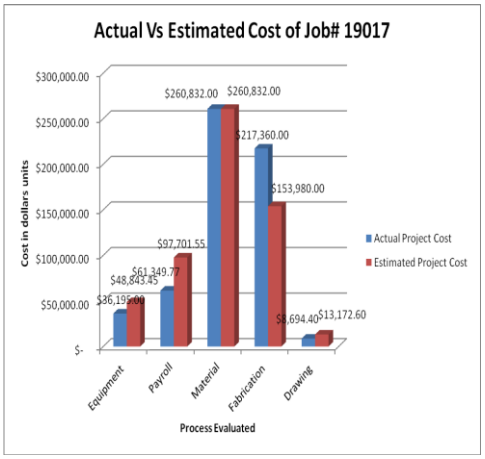

Figure 3
Actual Vs Estimated Cost Job#19017

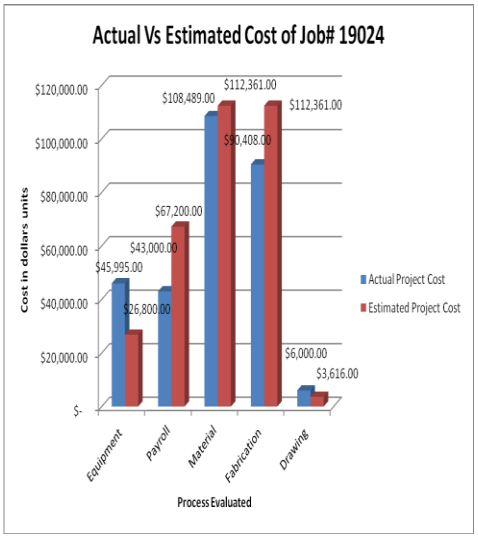

Figure 4
Actual Vs Estimated Cost Job#19024

This research demonstrates that if the information is evaluated independently improvement areas can be determined. Figures 3 and 4 demonstrate the different activities evaluated independently by project. The following statements can be concluded:

- Project 19017: Fabrication and material cost was higher than the estimated. Suppliers and fabrication costs should be monitored. If a particular activity uses all it cost the profit and overhead of the other activities will be consumed by these activities reducing the gross profit margin.
- Project 19024: The equipment cost was almost double than the estimate. The estimating activity should evaluate the site visited and correctly quote the equipment. This can avoid estimating particular equipment incorrectly and then have the need to use another type of equipment. If the field condition changes present this situation to the client and request a change order for the additional cost. If a particular activity uses all it cost the profit and overhead of the other activities will be consumed by this activities reducing the gross profit margin.

Document results for future reference

This final and most important step is to document the result to evaluate productivity constantly for areas of improvement. The construction industry in Puerto Rico lacks of Research and Development (R&D) in the productivity area. The general understanding that the industry has of a productive project is based on its profit, which is an inefficient and inaccurate determination parameter. The construction industry was evaluated based on productivity to reduce construction cost and increase that amount of capital available for project development.

CONCLUSION

This research demonstrates that it is extremely important to monitor the productivity in a steel installation construction project and the importance of correctly evaluating a project in the biding process. It was demonstrated that if all the areas of the construction project are not monitored, there could be a decrease of profit in a specific area. If this is not determined there is no need for improvement in the specific area affecting the productivity of the project. The industry continues to become more competitive and the increases in construction costs can cause the profit margin to fall in a negative range. With a constant productivity evaluation process this condition can be identified and addressed. The need to document and evaluate is critical for management in a construction company. The owner of the project is interested in the use of productive companies. If productivity techniques are correctly incorporated in construction companies, productivity will increase, increasing the profit and the opportunity to be competitive in the industry. Many construction projects have being awarded to outside companies that could have been awarded to local companies. The other companies have evaluated their productivity and lowered their costs to a point that they become equal or even better competitors than the local companies.

REFERENCES

[1] Structural Steel Work Inc, Retrieved on January 12, 2012 http://www.sswincpr.com/aboutus/pagebuilder .aspx/topicid

[2] Adrian, J. J., Ph.D., P.E., C.P.A. Bradley University Adrian International, L.L.C 1995, 2004. ISBN 1-58874-357-8

[3] Aace International Recommended Practice No. 25r-03 (2004). Estimation Lost Labor Productivity in Construction Claims

[4] International Cost Engineering Council, Retrieved on February 3, 2012, http://www.icoste.org/aace2006% 20papers/est08.pdf

[5] Torrasaya, M. Retrieved on February 3, 2012 http://www.juncosteel. com /nuestra2.html,

[6] United States Steel Corporation, Retrieved on January 6, 2012, http://www.uss.com/corp/company/profile /about.asp