**The 6th International Conference on Construction Engineering and Project Management (ICCEPM 2015)**
Oct. 11 (Sun) ~ 14 (Wed) 2015 • Paradise Hotel Busan • Busan, Korea
www.iccepm2015.org

# Investigating the Construction Industry from Key Performance Measurements

Kunhee Choi*[1], Hyun Woo Lee,[2], Junseo Bae[3], and Kyeong Rok Ryu[3]

***Abstract: The construction industry is an integral part of any nation's economy, whether measured by dollar volume or workforce size. In spite of its strong influence, there has been very little specifically aimed at evaluating the current industry performance. This research investigates the macroeconomic performance of the construction industry by accounting for crucial performance affecting factors such as labor productivity and gross margin. A clustering analysis, followed by a series of statistical analyses, yielded a notable finding that labor productivity is the most important factor that affects industry's profitability. The results of the analysis also revealed that the states with the strongest labor productivity show the highest level of profitability in terms of gross margin. This study should be of value to decision-makers when plotting a roadmap for future growth and rendering a strategic business decision.***

***Key Words: Labor productivity; Profitability; Cluster analysis; Census***

## I. INTRODUCTION

Construction industry is an integral part of any nation's economy, whether measured by dollar volume or work-force size. In spite of its strong influence on the economic health of nation, there has been very little specifically aimed at evaluating the current and future trend of labor productivity and industry's profitability. As a result, overall performance of the construction industry remains mostly unmeasured, and concerns have been constantly raised over no accurate measures of labor productivity and profitability.

Acquiring reliable labor productivity data has become a major problem in improving productivity for the industry. This research collects and documents detailed productivity data in order to quantify the macroeconomic performance of the construction industry in terms of labor productivity and firm's gross margin, which covers fifty states in the United States.

## II. RESEARCH OBJECTIVES AND METHODS

The major objectives of this study are twofold: 1) identify the most critical factors that affect the performance of the industry and 2) develop a regression model that can predict profitability of the industry. A clustering analysis was performed to identify the most critical factors. Adapting the approaches from a study by Choi et al. [1], the data for this research were collected from U.S. Economic Census Reports. The U.S. Census Bureau publishes a report every five years, and the three latest Reports of 1997, 2002, and 2007 were selected. The reports provide a detailed economic data of most sectors of the U.S. economy on the local, regional, and national levels. Following the study of Choi et al. [1], this study focuses on the statewide performance trend analysis through a hierarchical clustering analysis.

Inflation is an important parameter to be considered in macroeconomic studies because it can represent overall economic trends over time [2]. Similar to the study of Allmon et al. [3], the consumer price index was used to reflect the impact of price changes over the study periods.

With the adjusted and stratified census data, the objectives were achieved by a solid two-step methodology to 1) identify key macroeconomic parameters and thereafter 2) determine performance trends (i.e., a prediction model) at the state-wide level for the construction industry in U.S. Following are equations that were used to measure the key parameters:

- Labor productivity quantification:

$$\mathrm{LP_i} = \frac{\Sigma_{j=1}^{51} \mathrm{VC_{ij}}}{\Sigma_{j=1}^{51} \mathrm{NCW_{ij}}} \qquad \text{Equation 1}$$

where $LP_i$ ($LP_j$) = the labor productivity of state $i$; $VC_{ij}$ = the value of construction work in dollars; $NCW_{ij}$ = the number of construction workers.

- Labor wages:

$$\mathrm{LW_i} = \frac{\Sigma_{j=1}^{51} \mathrm{TP_{ij}}}{\Sigma_{j=1}^{51} \mathrm{NCW_{ij}}} \qquad \text{Equation 2}$$

where $LW_i$ ($LW_j$) = the labor wages of industry state $i$; $TP_{ij}$ = the total payroll; and $NCW_{ij}$ = the number of construction workers.

- Gross margin:

[1] Assistant Professor, Dept. of Construction Science, Texas A&M University, 3137 TAMU, Francis Hall 305, College Station, TX 77843-3137, kchoi@tamu.edu
[2] Assistant Professor, School of Civil and Construction Engineering, Oregon State University, 101 Kearney Hall, Corvallis, OR 97331, USA, Phone +1 541/737-8539, hw.chris.lee@oregonstate.edu
[3] Ph.D. Candidate, Dept. of Construction Science, Texas A&M University, 3137 TAMU, Francis Hall 328, College Station, TX 77843-3137, junsbae07@tamu.edu

$$GPC_i = \sum_{j=1}^{51}\left(\frac{Revenue_{ij}\text{-}G\&A\ Expenses_{ij}}{NCW_{ij}}\right) \quad \text{Equation 3}$$

where $GPC_i$ = the gross margin per construction worker (per establishment) for state $i$; $Revenue_{ij}$ = total revenue in state $j$ shown in industry sector $i$; $G\&A\ Expenses_{ij}$ = the general and administrative expenses in state $j$ shown in industry sector $i$.

Gross margin is defined as a firm's profit before operating expenses. The gross margin for the 51 states is calculated using industry revenue and general and administrative expense information, which includes employees' wages, equipment rental costs, capital expenditures, material costs and subcontractors' fees.

To ensure the robustness of the prediction model, the proposed model's accuracy and reliability in predicting firm's profitability was validated by a cross-validation statistical technique called the Predicted Error Sum of Square (PRESS). The PRESS statistic is computed by Equation 4 as the sum of the squares of the differences between each observation ($y_i$ in Equation 4) and the corresponding predicted value based on a model fit to the remaining n-1 points ($\hat{y}_i$* in Equation 4) [4].

$$PRESS = \sum_{i=1}^{n}(y_i - \hat{y}_i^*)^2 \quad \text{Equation 4}$$

The PRESS statistic is then compared to the Sum of Squared Error (SSE). SSE measures the discrepancy between observations and predicted values by summing the squared differences between each observation and the corresponding predicted value. The PRESS statistic that is close to the value of SSE suggests that the proposed model has a significant predictability. On the other hand, the PRESS statistic that is several times greater than SSE indicates a validation issue.

## III. Performance Trend Analysis

The statewide performance trend analysis was performed by a hierarchical clustering analysis that divides the 51 states into three clusters of statistically meaningful patterns. The following six independent variables were used:

1. Labor productivity per construction worker (LP)
2. Labor wages per construction worker (LW)
3. Percent of construction work subcontracted (SC%)
4. Percent of rental equipment use (Rental%)
5. Percent of labor cost (Labor%)
6. Percent of cost of materials, components and supplies (Mat%)

The dependent variable is set to GPE (i.e., Gross Margin per establishment). Figure 1 depicts a U.S. States map that is resulted from the clustering analysis. As shown in Figure 4, it is noteworthy that the states with geographical proximity share similar macroeconomic characteristics. Table 1 summarizes the states comprising each cluster in terms of the nine Census Divisions [5].

Following the hierarchical clustering, the step-wise regression backward elimination method is applied to each cluster to eliminate non-significant independent variables at each step. Based on the results of the step-wise regression, the PRESS and SSE statistics are computed and compared as validation of the developed models. Table 2 summarizes the results of the step-wise regression and validation of each cluster. Clusters 1 and 2 have two statistically significant variables that affect gross margin per establishment (GPE) while Cluster 3 has three significant variables. The ratios of PRESS to SSE close to 1 confirm significant predictability of each model.

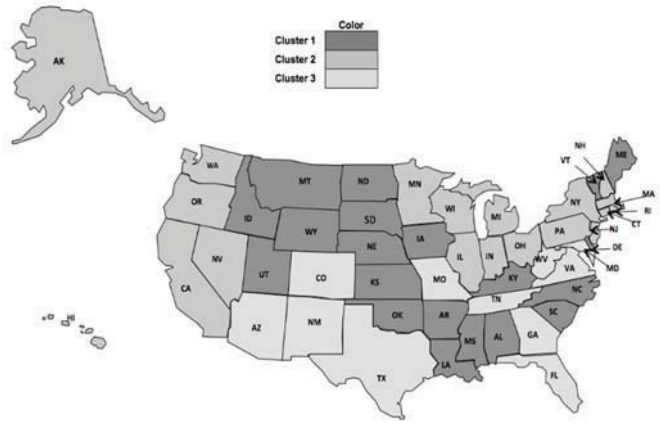


Figure 1: Result of Clustering Analysis

Table 1: Clustering Results at the Statewide Level

| Clusters | States in Clusters | Census Divisions |
|---|---|---|
| Cluster 1 | 20 States (AL, AR, DE, ID, IA, KS, KY, LA, ME, MS, MT, NE, NC, ND, OK, SC, SD, UT, VT, WY) | East South Central<br>Mountain<br>West North Central<br>West South Central |
| Cluster 2 | 19 States (AK, CA, CT, HI, IL, IN, MA, MI, MN, NV, NH, NJ, NY, OK, OR, PA, RI, WA, WI) | East North Central<br>Middle Atlantic<br>New England<br>Pacific |
| Cluster 3 | 12 States (AZ, CO, DC, FL, GA, MD, MO, NM, TN, TX, VA, WV) | Mountain<br>South Atlantic |

Table 2: Cluster-driven Predictive Models

| Clusters | Independent Variables | Coefficients | Standard Error | t-value | p-value | F-ratio | $R^2$ | Ratio of PRESS to SSE |
|---|---|---|---|---|---|---|---|---|
| Cluster 1 | Constant | 356.250 | 131.509 | 2.71 | 0.0093 | | | |
| | LP | 1.202 | 0.362 | 3.32 | 0.0017 | 12.8962[a] | 0.345 | 1.178 |
| | SC% | -13.115 | 3.809 | -3.44 | 0.0012 | | | |
| | Predictive Model | $GPE = 356.250 + 1.202\times LP - 13.115\times SC\%$ | | | | | | |
| Cluster 2 | Constant | -655.852 | 272.443 | -2.41 | 0.0198 | | | |
| | LP | 1.986 | 0.527 | 3.77 | 0.0004 | 9.2056[b] | 0.239 | 1.186 |
| | Rental% | 346.658 | 122.585 | 2.83 | 0.0067 | | | |
| | Predictive Model | $GPE = -655.852 + 1.986\times LP + 346.658\times Rental\%$ | | | | | | |
| Cluster 3 | Constant | 253.697 | 166.608 | 1.52 | 0.1387 | | | |
| | LP | 2.575 | 0.355 | 7.26 | <0.0001 | 19.7041[a] | 0.671 | 1.308 |
| | SC% | -5.768 | 2.140 | -2.70 | 0.0116 | | | |
| | Mat% | -10.995 | 4.963 | -2.22 | 0.0347 | | | |
| | Predictive Model | $GPE = 253.697 + 2.575\times LP - 5.768\times SC\% - 10.995\times Mat\%$ | | | | | | |

a Significant at <0.0001
b Significant at <0.001

There are five major findings that can be drawn from the analysis results. First, labor productivity is consistently determined to be a statistically significant variable for every model, while labor wages have no statistically meaningful relationship with gross margin. The coefficients of labor productivity in each model indicate that a $1 increase in labor productivity can lead to a $1.202, $1.986, or $2.575 increase in gross margin in the states of Clusters 1, 2, or 3, respectively. This finding agrees with the results of the macroeconomic trend analysis at the sub-sector level. Therefore, both trend analyses consistently

confirm that labor productivity is the most crucial factor that determines the profitability in the construction industry.

Second, the models for Clusters 1 and 3 indicate that the percent of construction work subcontracted (SC%) has a statistically significant negative impact on the gross margin. This finding concurs with the industry-wide pricing practice where construction firms allocate lower markups on subcontracted items than on self-performing items [6]. Construction firms tend to reduce their markups on subcontracted items for two reasons: (1) a subcontractor's estimate submitted to contractors already includes their own markup and job overhead, and (2) contractors can reduce their contingency for the subcontracted amount by shifting the risk of cost overruns to the subcontractor [7]. Therefore, the increased amount of subcontracting can lead to a reduction in the nominal margin of contractors. In addition, managing more subcontracts can increase a firm's management cost, which may result in a reduction in profitability [8]. According to the nine Census Divisions [5], this finding is applied to the Mountain, West North Central, West South Central, East South Central, and South Atlantic Divisions.

Third, the model for Cluster 3 indicates that percent of cost of materials, components and supplies (Mat%) also has a statistically significant negative impact on gross margin. This implies that projects with lower material costs are likely to achieve higher profitability. The industry shares a notion that there is less risk in pricing materials than in pricing labor or equipment [7]. Therefore, it may be the case where construction firms tend to reduce their markups on the cost of materials because of a perceived reduced risk exposure, which in turn could reduce their overall gross margin if the material cost of a job is significantly high. This finding represents the Mountain and South Atlantic Divisions.

Fourth, the model for Cluster 2 indicates that an increased use of rental equipment (Rental%) can lead to increased gross margin. Contractors that own and maintain a fleet of equipment are exposed to the financial risk related to ownership costs, including depreciation, interest, insurance, and taxes [9]. By utilizing rental equipment, contractors can therefore shift such risk to rental companies, and hence can increase profitability. In that regard, the industry has been observing the increased use of rental equipment in recent years [10]. This finding is applicable to the East North Central, Middle Atlantic, New England, and Pacific Divisions.

Lastly, the impacts of labor wages per construction worker (LW) and percent of labor cost (Labor%) on gross margin are determined to be statistically insignificant in any of the clusters. This finding agrees with the result of the sub-sector trend analysis that has found no significant correlation between labor wages and gross margin.

## IV. Conclusion and Discussion

There have been a number of studies aimed at determining the macroeconomic performance of the overall U.S. construction industry. However, the lack of reliable data has made it difficult to draw conclusive results among different studies, which ultimately hinders efforts to measure and improve the performance of the industry. Besides, there have been no studies to determine the macroeconomic performance of the construction industry at the statewide level.

To address these shortcomings, the present study identified the U.S. Economic Census Reports of 1997, 2002 and 2007 as the direct and reliable macroeconomic data. The goal of the present study was to apply a series of statistical analyses to identify and measure factors that influence the performance of the construction industry. The novelty of the study lies in the extensive quantification of macroeconomic performances of the industry at a statewide level.

The statewide cluster-driven trend analysis divides the 51 states into three statistically meaningful clusters. By examining six independent variables that could affect firms' profitability within each cluster, the step-wise regression technique was used to develop a predictive model for each cluster, which determines firms' profitability at the statewide level. The results of the analysis revealed that the states with the strongest labor productivity show the highest level of profitability in terms of gross margin. The results also clearly covey a notable conclusion that labor productivity is the most significant factor affecting firms' profitability. It is therefore critical for construction firms to develop ways to achieve improved productivity in order to accomplish a greater level of profitability.

To the best of the authors' knowledge, this research study is the first of its kind. Therefore, this study can be viewed as a significant leap forward in understanding the strengths, weaknesses, and needs of the construction industry. This study can accordingly help decision-makers in the construction industry devise forward-thinking business strategies. The findings of this study should also be of value to planners who need to plot a proactive map for future growth. To this end, the predictive models developed in this study can support their efforts in reliably predicting a firm's profitability.

## References

[1] Choi, K., Haque, M., Lee, H. W., Cho, Y. K., and Kwak, Y. H., 2013. Macroeconomic labor productivity and its impact on firm's profitability. Journal of the Operation Research Society 64(8), 1258–1268.

[2] Bureau of Labor Statistics, Consumer Price Index. [Online] Available at: http://www.bls.gov/cpi/.

[3] Allmon, E., Haas, C. T., Borcherding, J. D., and Goodrum, P. M., 2000. US construction labor productivity trends, 1970–1998. Journal of Construction Engineering and Management, 126(2), 97–104.

[4] Montgomery, D. C., and Runger, G. C., 2010. Applied Statistics and Probability for Engineers. John Wiley & Sons, Hoboken, NJ.

[5] U.S. Census Bureau, Geographic Terms and Concepts-Census Divisions and Census Regions. [Online] Available at http://www.census.gov/geo/reference/gtc/gtc_census_divreg.html.

[6] Dagostino, F. R. and Feigenbaum, L., 2002. Estimating in Building Construction, 6th Edition.

[7] Pratt, D., 2010. Fundamentals of Construction Estimating, 3rd Edition.

[8] Beach, R., Webster, M., and Campbell, K.M., 2005. An evaluation of partnership development in the construction industry. International Journal of Project Management 23(8), 611–621.

[9] Gransberg D. D., Popescu, C. M., and Ryan, R., 2006. Construction Equipment Management for Engineers, Estimators, and Owners, CRC Press.

[10] Agoos, A., 2011. Trends in Owning vs. Renting Construction Equipment. [online] Available at http://www.forconstructionpros.com/document/10658556/trends-in-owning-vs-renting-construction-equipment.