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INFLUENCE OF QUALITY ON CONSTRUCTION COSTS

ABSTRACT

This work tests the truth of the construction industry paradigm that cost, schedule, and quality form a triangle and that increasing any one of these attributes will adversely impact the other two. The study examines the correlation between quality measures (such as construction deviations and length of punchlist) and construction costs measures such as total project cost, construction cost, design costs, and construction change order cost). Based on data from over 50 large, public sector, educational building program projects completed over the last 5 years, this paper also suggests best practices for cost engineers and project managers working for other public sector agencies. Conclusions to the paper include suggestions for expansion of the research/lessons learned, as well as future research of factors that influence project cost and quality.

INTRODUCTION

As one of the largest public sector building programs in the United States, the Los Angeles Unified School District is in the middle of twelve year building program. Given the magnitude and duration of the program, the District has undertaken studies as to how to improve their project delivery. This work summarizes the District's analysis of the construction industry paradigm that cost, schedule, and quality form a triangle and that increasing any one of these attributes will adversely impact the other two. The study examines the correlation between project quality measures and project cost measures. This paper presents the study findings and suggests best practices for managing quality for other public sector agencies. Conclusions to the paper include suggestions for expansion of the research/lessons learned, as well as future research of factors that influence the cost and quality relationship.

BACKGROUND

Data for this study comes from traditional low bid, building construction work from the new construction program currently underway at the Los Angeles Unified School District (LAUSD). The District is in the middle of building new schools and making their existing schools better through the largest school construction and repair program – $19.2 Billion – in the nation's history. The building program will complete more than 150 new schools for the students of Los Angeles, and when complete in 2012, the program will have built the equivalent of San Diego's entire school district within Los Angeles. In addition, thousands of much needed projects in existing facilities will be completed during the same period. Funding has been identified from various sources including State Proposition 1A bonds, local Proposition BB Bonds, and developer fees [1].

The data set for the project is mixed. Basic project scope and cost data (related to total project cost, construction costs, and design cost) is available on 130 completed projected of two different types – additions (a new classroom building on an existing school) and new schools (entirely new schools on newly acquired properties). Within the New Schools group two types of projects exist based on project size – Primary Centers (16 classroom small schools for kindergartners through second graders) and Elementary, Middle, or High School projects (typically 40 to 50 classroom schools for children from all grades including High School). The projects have all completed construction as of December 2006. Not every project of the 130 has quality data records available. Of the 130 projects, 40 have records of deviations and 17 have data related to punchlists. Data for the project set is shown in Table 1.

TABLE 1. LAUSD DATA CHARACTERISTICS

	Total Project Cost	Design Cost	Construction Cost	Change Order Percentage	Number of Items on Initial Punchlist	Number of Deviations
Mean	$19,066,382	$897,762	$12,247,402	4.66%	3,112	125
Median	$15,745,806	$738,211	$7,136,138	2.87%	2,222	60
Minimum	$1,694,975	$104,401	$102,032	-2.12%	810	1
Maximum	$116,038,033	$4,021,312	$101,186,946	37.44%	12,223	1,500

ANALYSIS

Analysis examines correlations between project quality measures and project cost measures. Specific project variables to be examined are:

- Number of Punchlist Items (quality measure)
- Number of Construction Deviations (quality measure)
- Total Project Cost (cost measure)
- Construction Cost (cost measure)
- Design Cost (cost measure)
- Design Cost per Square Foot (cost measure)
- Number of Change Orders (cost measure)
- Change Orders as a Percentage of Construction Cost (cost measure)

Within this study, a punchlist is a list of incomplete, incorrect, or somehow flawed items at the end of a construction project (typically related to finishes). A deviation is a significantly incorrect item that occurs during the course of the construction (typically related to building systems).

Figure 1 shows the relationship between construction cost and punchlist length. As shown in the figure, the greater the value of the construction project, the greater the number of punchlist items. Figure 2 shows the relationship between construction cost and number of deviations. Similar to Figure 1, Figure 2 shows that the greater the value of the construction project, the greater the number of deviations. The results of neither Figure 1 nor Figure 2 are surprising. As a project gets larger it seems logical to assume the more quality issues would arise based on the fact that a larger project would have a larger number of opportunities for quality flaws. The correlation coefficients for the best fit line for both projects (0.2826 and 0.1358) are surprisingly high indicating a strong relationship between the variables.

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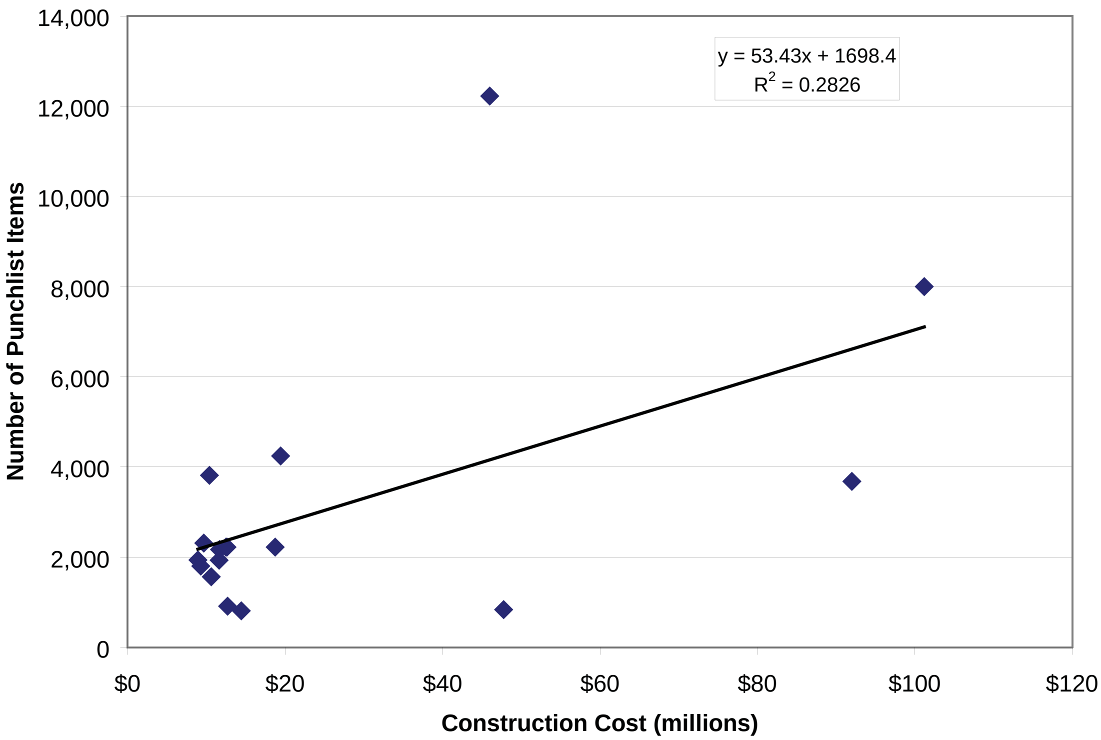

Figure 1. Number of Punchlist Items verses Construction Cost

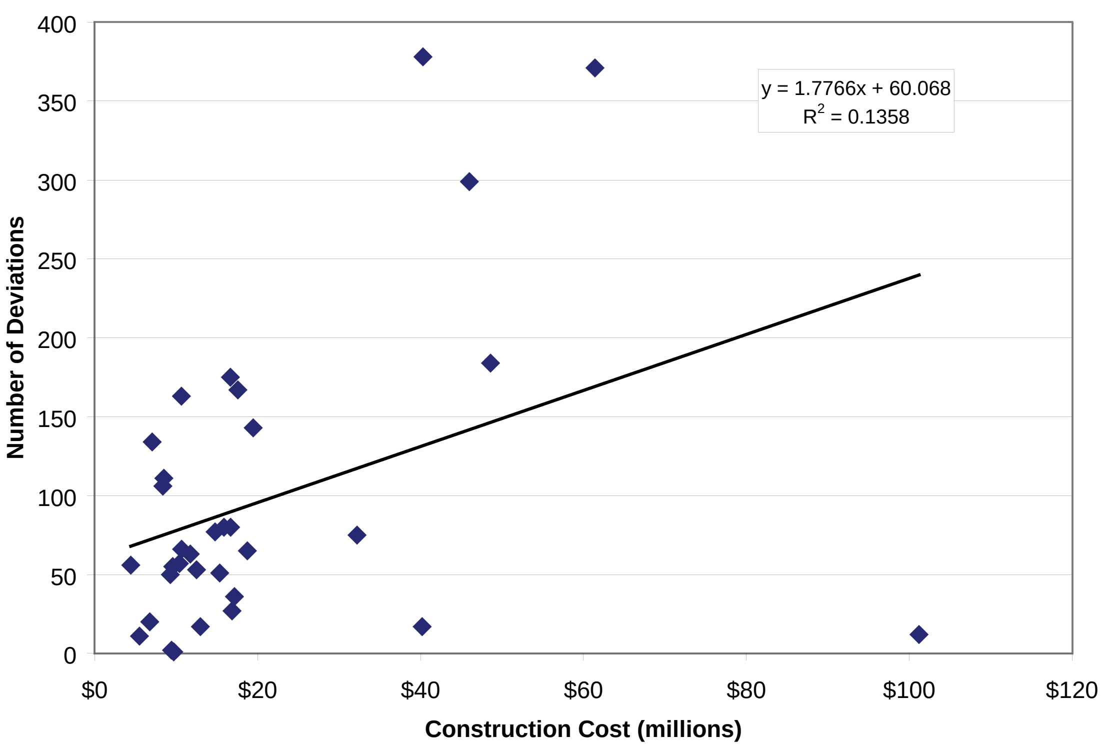

Figure 2. Number of Deviations verses Construction Cost

Figure 3 shows the relationship between total project cost and punchlist length. Figure 4 shows the relationship between total project cost and number of deviations. Based on the results of Figures 1 and 2, it was expected that again as the total project cost increased more quality issues would arise based on the fact that a larger project would have a larger number of opportunities for quality flaws. Surprisingly, both figures showed the opposite trend. The two figures show that the greater the total project cost, the lower the number of punchlist items and deviations. Recognizing that total project cost includes project management and design costs in addition to construction cost, perhaps the reason for this trend reversal is in the influence of design diligence (translated into a greater fee and a greater total project cost) or more project manager involvement (translated into a more hours billed and a higher total project cost).

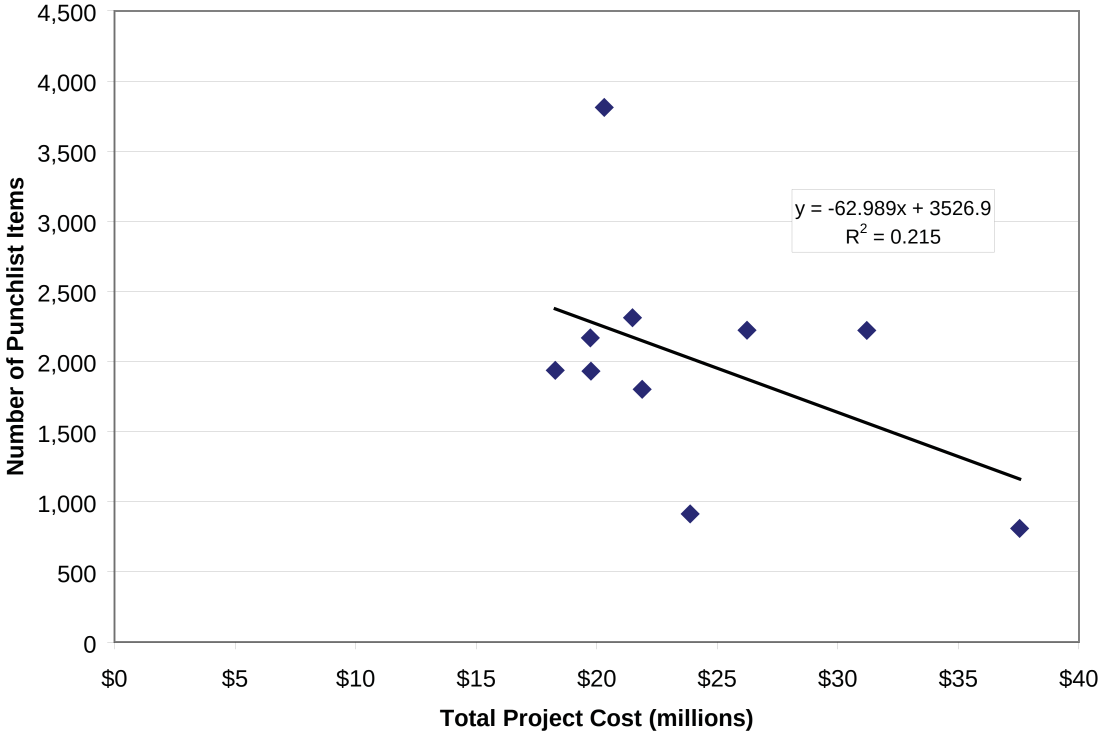

Figure 3. Number of Punchlist Items verses Total Project Cost

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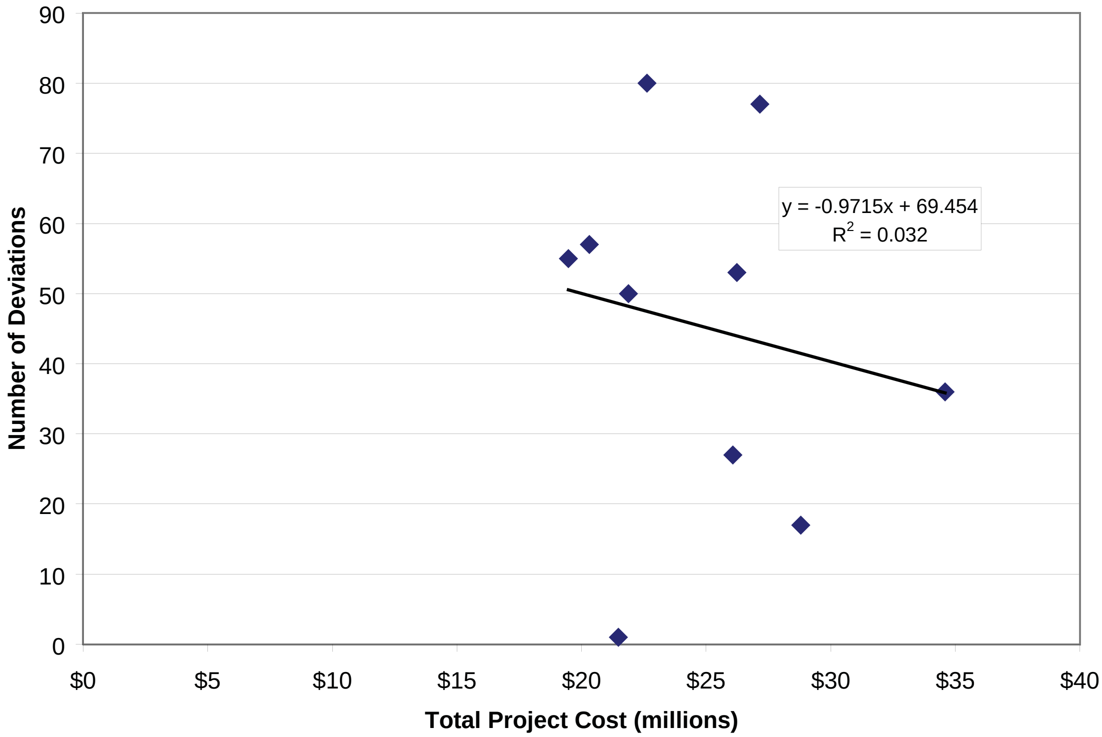

Figure 4. Number of Deviations verses Total Project Cost

Figures 5 and 6 study whether a relationship exists between change orders and quality. It would be expected that if change orders were high (either in number or percentage of construction contract value) then the design quality was poor and project quality measures would be adversely impacted (longer punchlist and greater number of deviations). Figure 5 shows that the number of deviations increases with an increase in change orders. Figure 6 shows that the number of deviations also increases as the change order percentage increases. The behavior shown in both of these figures is as expected. A similar analysis using number of punchlist items rather than number of deviations was also conducted (but not shown in this work in order to adhere to manuscript length requirements). Interestingly, no correlation was found between these variable perhaps because change orders occur during the course of construction of a project while a punchlist is generated after completion of construction.

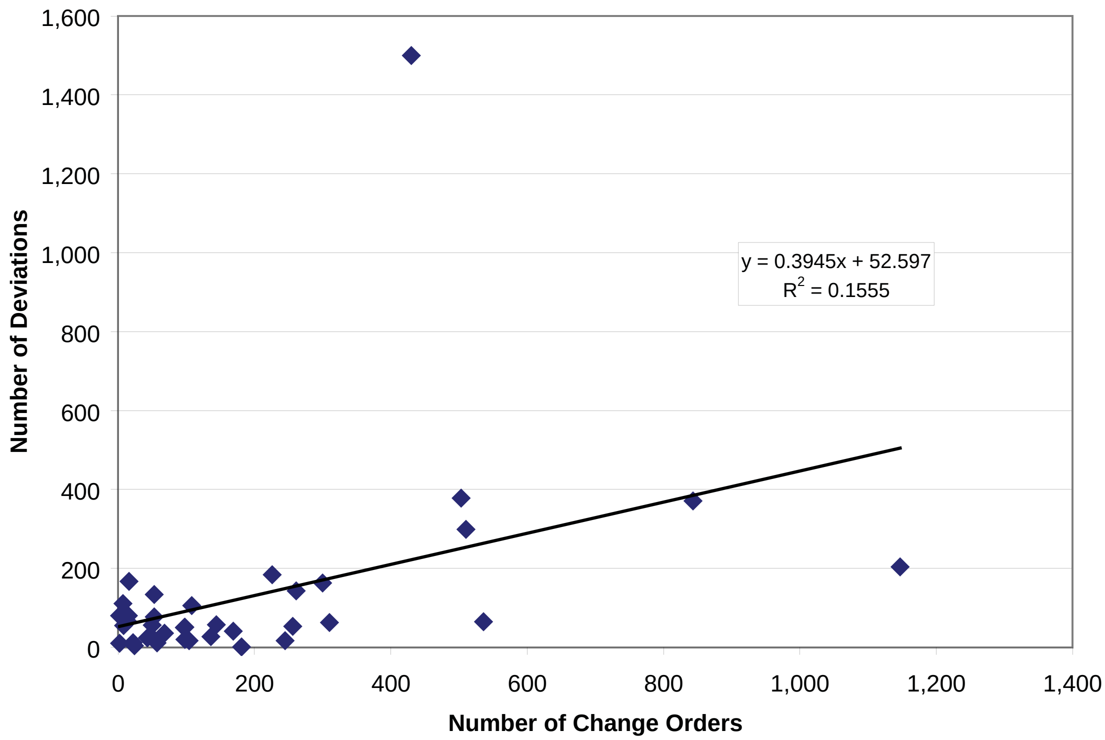

Figure 5. Number of Deviations verses Number of Change Orders

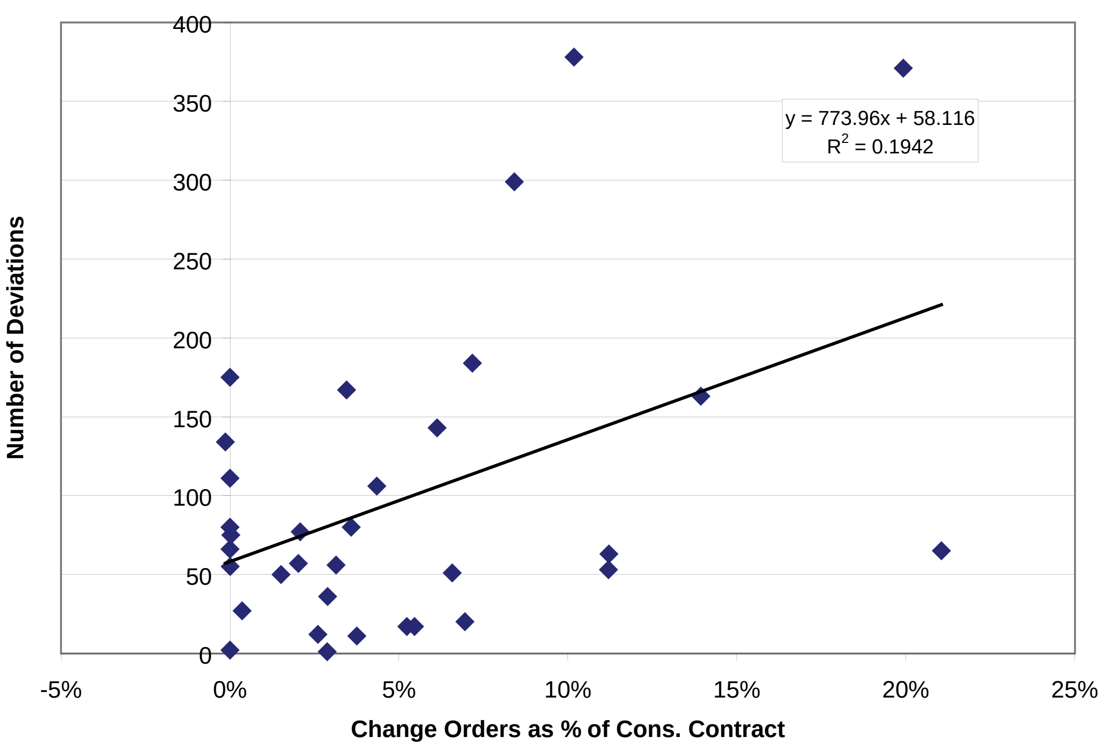

Figure 6. Number of Deviations verses Change Order Percentage of Construction Cost

Figures 7 to 10 test the logic used to explain the trend shown in Figures 3 and 4. Recall, these two figures seemed to indicate that increased designer involvement reduces the quality issues on a project. Figure 7 shows the relationship between design cost and punchlist length. Figure 8 shows the relationship between design cost and number of deviations. Figure 9 shows the relationship between design cost per square foot of building constructed and punchlist length. Figure 10 shows the relationship between design cost per square foot of building constructed and number of deviations. The four figures show that greater designer costs (on a total cost basis or on a cost per square foot basis) reduce the number of punchlist items and deviations. These figures seem to confirm the logic used to explain the trends seen in Figures 3 and 4.

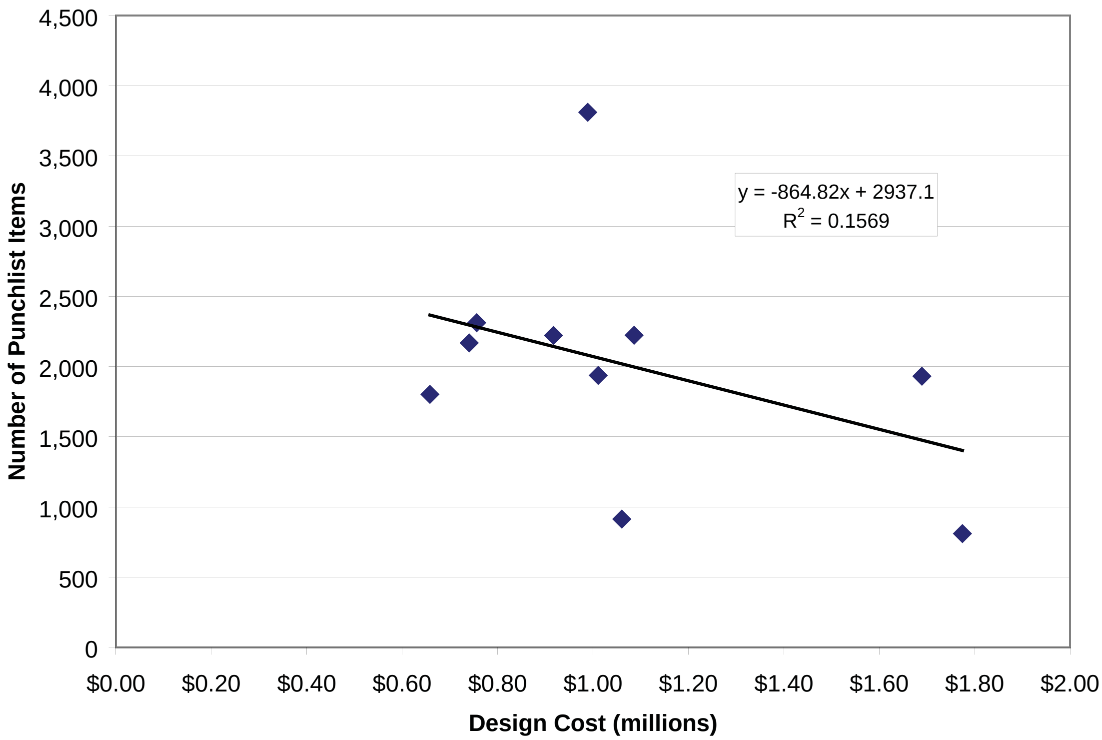

Figure 7. Number of Punchlist Items verses Design Cost

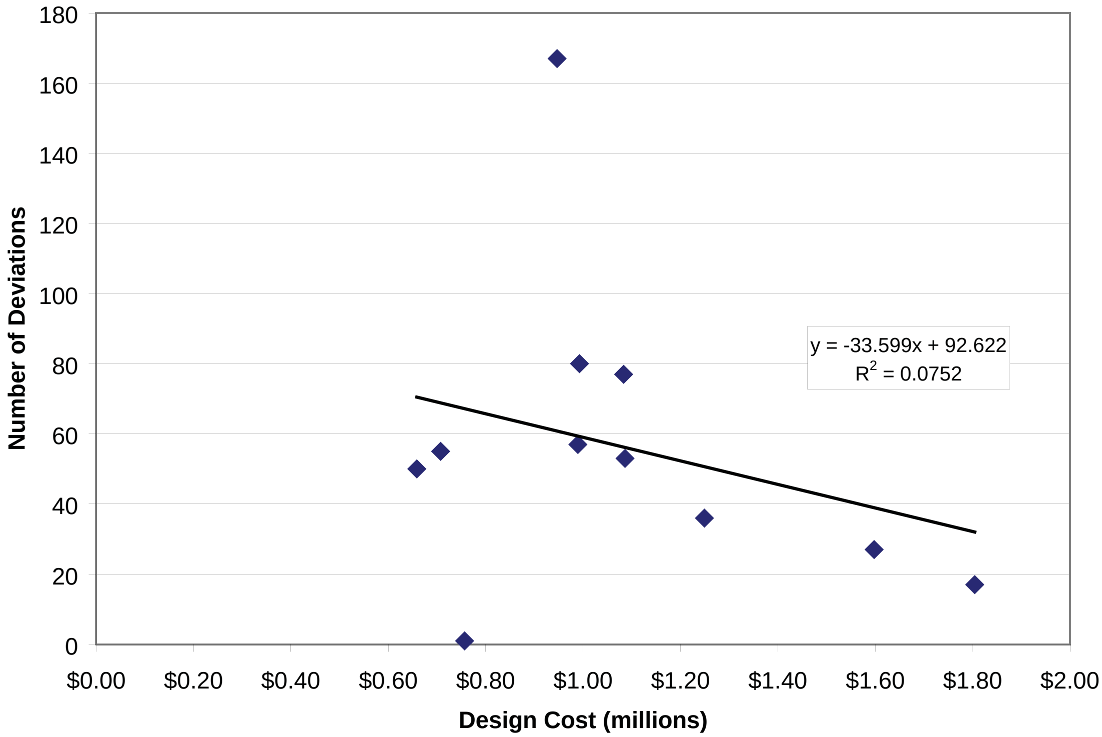

Figure 7. Number of Deviations verses Design Cost

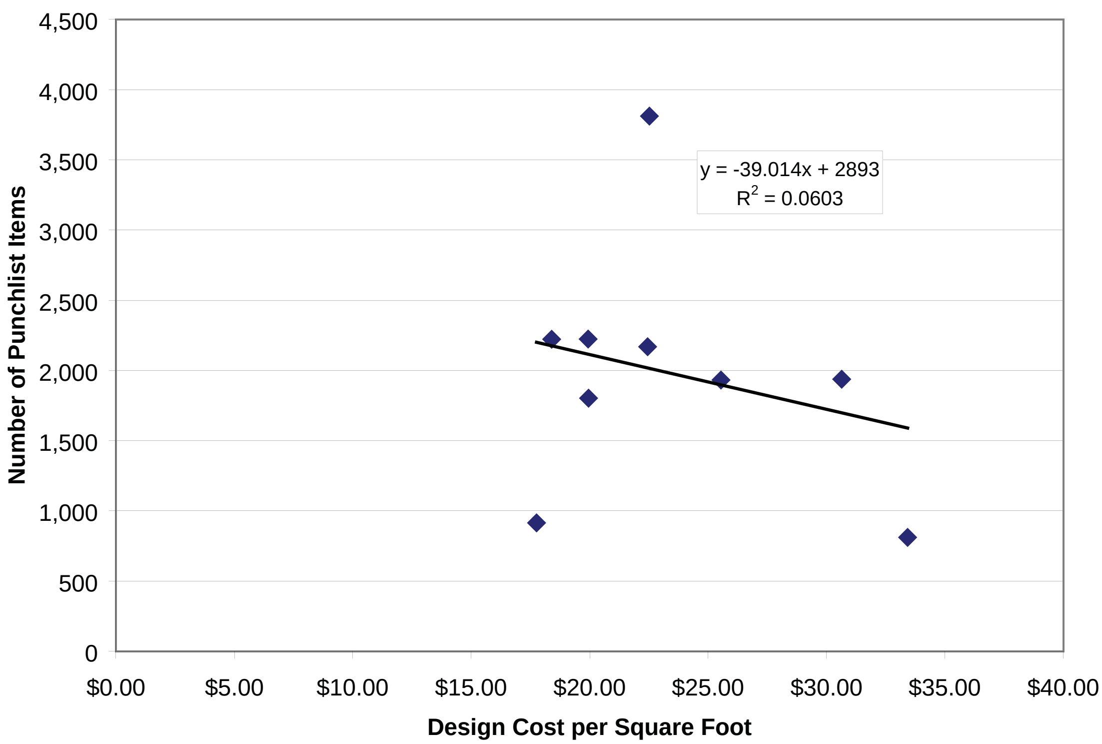

Figure 8. Number of Punchlist Items verses Design Cost per Square Foot

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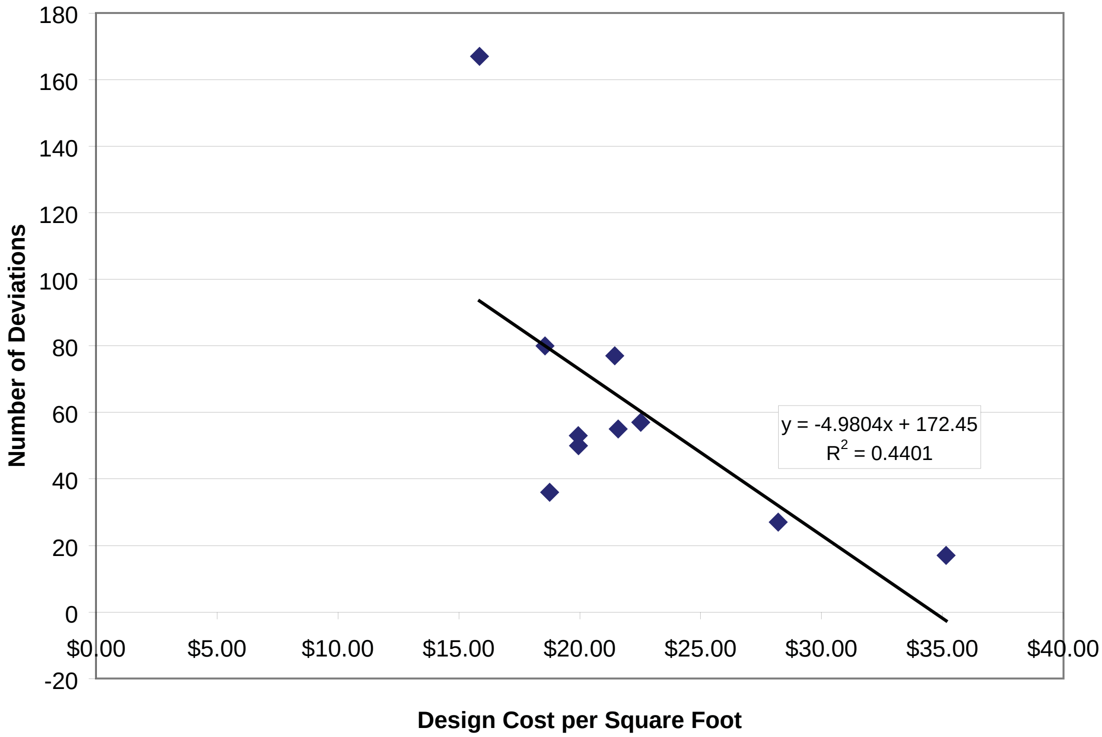

Figure 9. Number of Deviations verses Design Cost per Square Foot

LESSONS LEARNED AND CONCLUSIONS

This research has examined the relationship between quality and cost for a data set of recently completed projects for the Los Angeles Unified School District. The study found that:

- Increased construction cost increases the number of quality issues (measured as both deviations and punchlist list items)
- Increased total project cost decreases the number of quality issues (measured as both deviations and punchlist list items)
- More change orders (measured as either number of occurrences or as a percentage of construction cost) decreases the number of quality issues when measured as deviations but does not influence quality when measured as punchlist list items
- Increase in Design cost (measured either in total cost or total cost per square foot of building designed decreases the number of quality issues (measured as both deviations and punchlist list items)

Lessons learned are intuitively evident with respect to design cost. Time and money spent on the design phase of a project will result in fewer quality related problems during construction. This lesson is consistent with Paulson's classic level of influence theory in construction [2]. Owners, project managers, and cost engineers should recognize this fact when budgeting costs and setting schedules for design of future projects. Not as easy to interpret are lessons with respect to total project and construction costs. It seems that elements included within the total project costs (design, management, inspection, testing) have a positive impact on construction quality. Further research is needed to better understand these relationships and influences. Given the large size of the LAUSD building program and the tremendous quantity of data, numerous opportunities exist for future research. Beyond expansion of this study with additional data, future research should focus on the areas identified above and on design and construction duration impacts to construction quality.

REFERENCES

1. Los Angeles Unified School District, Facilities Services Division (2005). New Construction Strategic Execution Plan for 2005
2. Paulson, Boyd C. (1976). "Designing to Reduce Construction Costs," Journal of the Construction Division, Vol. 102. No. CO4, pp. 588