

# DEVELOPMENT OF LIQUIDATED DAMAGES FOR THE OKLAHOMA DEPARTMENT OF TRANSPORTATION

ODOT SPR No. 2120

August 2009

---

## Problem Statement

Federal regulation 23 CFR 635.127 requires that the Oklahoma Department of Transportation (ODOT) must establish liquidated damages (LD) for projects contracted in Oklahoma. The ODOT is required by the Federal Highway Administration (FHWA) to review, update when necessary and submit them every two years for approval (1). According to FHWA, the method used to develop a standard LD schedule should use construction engineering costs associated with the type and size of work encountered. The FHWA method has four steps: 1) determination of requisite data, 2) collection and organization of data, 3) calculation of workday LD rates and 4) calculation of calendar-day LD rates (1). This means that a defensible method of calculating agency LD charges in the post-contract, pre-project completion period must be developed and then re-evaluated and applied on a biennial cycle.

## Proposed Research

The objectives this research were to evaluate the previously presented Auburn University- Alabama Department of Transportation protocol (2) used to determine LDs in Alabama and to modify it as necessary and apply it to a data base supplied by ODOT. This effort included the evaluation, screening and qualifying of the ODOT

data for the development of liquidated damages. These data and the selected methodology were then applied to the ODOT's data base to determine a statistically defensible daily rate for agency charges when projects are not completed within the original schedules.

## Scope

As stated, this work was built upon that developed at Auburn University for the Alabama Department of Transportation (2) but utilized data provided by ODOT and investigated more thoroughly ways to determine sample outliers, determine project size breakpoints as well as aggregating data sets across project sizes.

The sequence of activities completed for this effort included:

- A preliminary evaluation of the data set provided by ODOT.
- Grouping data across project sizes.
- Determination of outliers within project sizes; comparison of alternative methods.
- Evaluation of the Auburn University LD metrics: % Engineering and Inspection (%EI) and Dollars per day (\$/Day).
- Combine similar project sizes for LD determinations.
- Determination of LDs for the total ODOT data set for grouped data.

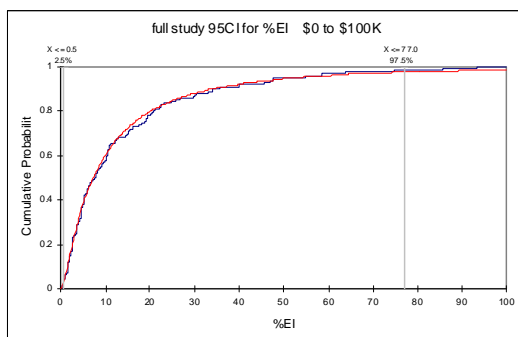
## Data Analysis

The data provided by ODOT contained information from 1,033 contracts covering the years 2005 - 2007. It is unknown by the authors whether the ODOT supplied data contain the appropriate overhead charge. The variables of concern from the ODOT data set included the Contract Amount, the Calendar Days Allowed, the Distributed Amount and the Cost per Calendar Day. Engineering and Inspection costs (%EI) and dollars per day (\$/Day) were calculated according to the following formulas:

$$\%EI = \frac{\text{Distributed Amount}}{\text{Contracted Amount}} \times 100$$

$$$/\text{Day} = \frac{\text{Contracted Amount}}{\text{Calendar Days Allowed}}$$

The ODOT data set was separated into the following project size delineations: <\$100K, \$100K-\$200K, \$200K-\$500K, \$500K-\$1M, \$1M-\$2M, \$2M-\$5M, 5M-\$10M and >\$10M. The two metrics, %EI and \$/Day were used to identify outliers within each project grouping by fitting Cumulative Density Functions to each data subset and then eliminating all data >97.5% or <2.5%. That is, retaining the interior 95% of all data. A typical cumulative density function is shown below.



The next step in the determination of Liquidated Damages was to evaluate the qualified data sets, minus the outliers, for statistical similarity to each other. Two approaches were used to address these possible similarities, Kruskal Wallis H test and one-way analysis of variance (ANOVA). Statistically similar project size groupings were then combined for ease of analysis and to prevent redundancies. A total of three subgroups were identified using %EI as the evaluation metric while \$/Day produced six.

Preliminary Liquidated Damages were then determined to be the median (or mean) of the Cost Per Calendar Day values in the original ODOT data set subject to outlier qualification and composited project sub-grouping. Final LDs include a conversion from calendar days to working days. The authors do not know if the data supplied contained ODOT's overhead rate. Therefore, the LDs are based on the original data and might need to be adjusted by the appropriate ODOT overhead rate.

## Conclusions

1. It is unknown by the authors whether the ODOT provided data set contained the appropriate overhead rate. Therefore, LDs are identified as preliminary and may need to be multiplied by ODOT's overhead rate.
2. The ODOT provided data set was divided into 8 subsets based on project sizes.
3. The Auburn University measurement variables %EI and \$/Day were generated from the ODOT data.
4. Outliers for each project size were determined by fitting a cumulative statistical distribution

- for each of the Auburn measurement variables.
5. Outliers were classified as those with probabilities  $>97.5\%$  and  $<2.5\%$ .
  6. Kruskal-Wallis and a One-Way ANOVA were used to determine if the original 8 project sizes could be grouped together into a smaller number. A series of multiple comparison tests were employed to identify which groups were similar. There was some uncertainty in these classifications.
  7. The means and medians of the original ODOT variable "Cost per Calendar Day" were determined on the grouped, qualified data. Alternatively these are the liquidated damages for the various project size groupings.
  8. Kruskal-Wallis and a One-Way ANOVA were used to determine if the original 8 project sizes could be grouped together into a smaller number. A series of multiple comparison tests were employed to identify which groups were similar. Of the eight original groupings, three groupings were identified using the metric %EI and six were identified using \$/Day.
  9. The median values resulted in more consistent LDs across the groupings and, due to the typically skewed data, are a better representation of the central value of each group than the mean.

## Recommendations

Below are the recommended sequences of actions for biannually determining Liquidated Damages:

1. Visually examine all data for any noticeable abnormalities. Exclude them.
2. Group data by project size in a manner consistent with the agency's management objectives.
3. Use Auburn University's measurement parameters: %EI and \$/Day to characterize the data sets.
4. Within each project size determine the central 95% of the data. For this effort a statistical distribution was fitted to the respective data and the central 95% determined. Alternative approaches are also possible.
5. Test statistically by application of either or both the Kruskal-Wallis or One Way Analysis of Variance (ANOVA) to determine whether the project groupings contain similar data.
6. If similarities exist, use various multiple comparison tests to determine which groupings are similar. For this effort %EI produced a total of three overall groups while \$/Day generated six. Alternatively, ODOT could use the entire project groupings produced in step 2 if their management objectives were better met by having consistent management groups.
7. Within each of these combined groupings or in the original number of project designations, the ODOT classification "Cost per Calendar Day" is then used in the qualified data sets.

8. The means and the medians of the respective, qualified “Cost per Calendar Day” are then calculated. These values times an appropriate overhead rate are the calendar day liquidated damages (LD).
9. Working day liquidated damages are determined by multiplying these calendar day determinations by 1.40 (7/5<sup>ths</sup>).
10. For this effort the medians produced a more consistent LD calculation.

Based on the analysis performed on the ODOT data set, Preliminary Liquidated Damage rates were obtained for calendar days and working days based on median values from the qualified data set using the metric \$/Day for six contract size groupings and from median values from the qualified data set using the original eight groupings. To determine a final LD rate it may be necessary to multiply the preliminary LDs by the appropriate ODOT overhead rate. Working days are 1.4 (7/5) times calendar days.

## References

1. Crowley, L.G., W.C. Zech, C. Bailey and P. Gujar. “Liquidated Damages: Review of Current State of the Practice.” *ASCE Journal of Professional Issues in Engineering Education and Practice*, Vol. 121, No. 4, October 2008, pp. 383-390.
2. Zech, Wesley C., Larry G. Crowley and Clark B. Bailey. *Development of a Procedure for Updating Liquidated Damage Rates Used in ALDOT’s Construction Contracts*. Final Report, Project Number: 930-

656, Highway Research Center,  
Department of Civil Engineering,  
Auburn University, Auburn  
University, Alabama, October  
2008.

## Contacts

### Principal Investigators

William F. McTernan, Ph.D., P.E.  
School of Civil and Environmental  
Engineering  
Oklahoma State University  
Stillwater, OK 74078

Stephen A. Cross, Ph.D., P.E.  
School of Civil and Environmental  
Engineering  
Oklahoma State University  
Stillwater, OK 74078

### ODOT Research Division

Ron Curb, P.E. (404-522-3795)  
Planning & Research Division  
200 N.E. 21<sup>st</sup>, Rm 3-A7  
Oklahoma City, OK 73105