# SIMULATION EXPERIMENTS TO EVALUATE AN ALTERNATIVE TO ONE FACTOR ANOVA

*Edward P. Markowski, College of Business and Public Administration, Old Dominion University, 5115 Hampton Blvd, Norfolk, VA 23529, 757-683-3533, emarkows@odu.edu*

## ABSTRACT

One-way analysis of variance is a common topic in introductory business statistics classes. However, considering all of the alternative topics that should be included, limited time is available for this topic. In the course we teach, we try to complete this topic in no more than one and a half classroom hours. Some courses eliminate it altogether and some textbooks present it only as a supplementary topic and only include it on a supplementary CD but omit it from the actual textbook.

A thorough unit on one way analysis of variance requires substantial time for a number of reasons. First of all, an introduction to the elements of the ANOVA table such as sums of squares and mean squares is a bit tedious. In addition, an introduction to the F-distribution and corresponding table must be done. Secondly, a discussion of the need for and execution of multiple pairwise comparisons needs to be completed. Additionally, some discussion about underlying assumptions such as homogeneity of variance is necessary.

Standard introductory business statistics textbooks vary in their discussion concerning violations of the homogeneity of variance assumption. While this assumption is always listed, some textbooks provide no advice concerning how to detect violations of the assumption or how to proceed if the assumption is violated. Some others recommend (unwisely) conducting a test of equality of variance such as the tests of Hartley or Bartlett. Some better treatments are to mention the robustness of traditional ANOVA with equal sample sizes and, with reference to tests of equality of variance, provide the disclaimer that use of these tests in ANOVA is controversial. Our conclusion in our review of business statistics texts is that the ramifications of violating the equality of variance assumption are either ignored, questionable statistical tests are proposed, or the complex modified-Levene test is presented. So, the simpler presentations are to some degree inadequate while the more complex approach requires even more time to be devoted to the topic of one way analysis of variance.

In this paper, we evaluate a methodology for comparing means of multiple populations without reference to the traditional analysis of variance and without the need for the homogeneity of variance assumption. This methodology was first proposed by Markowski and Markowski (2008). This approach can substitute for the usual one-way ANOVA and can be presented in a much shorter period of time. It includes results of conducting all pairwise comparisons among population means. In addition, the approach does not require any assumption of equality of variance among the populations.

In two-sample problems, an alternative to the pooled t-test that is less sensitive to the equal variance assumption is the separate variances t-test with Satterthwaite approximation for degrees of freedom. This test has often been called the Welch test and, as a result we will refer to it as W. Our approach to comparing multiple population means is to generalize from the W test by conducting all possible pairwise comparisons among the means using the W test for each comparison. However, without some adjustment, the experimentwise error rate associated with the set of comparisons will be too high. We use a straightforward adjustment of the significance level using the Bonferroni method.

In this study, we report the results of an extensive simulation study comparing the proposed method with the traditional approach to one-way ANOVA including the preliminary F-test and more importantly,

Tukey-Kramer pairwise multiple comparisons. Factors that are varied in the simulation study include number of groups (up to 5), sample sizes (both equal and unequal with various patterns and ratios of sample sizes), and population variances (various patterns of inequality as well as the equal variances case). Competing methods are evaluated both on the extent of agreement between the actual significance level and the stated (nominal) level and on the power of the two testing procedures for the experimental design outlined above. Preliminary results of our experiments suggest that the proposed method has both advantages and disadvantages relative to traditional ANOVA in the comparisons of actual and nominal level.